NON-NATIVE SPECIES MONITORING AND CONTROL, SAN JUAN RIVER 1999-2001

PROGRESS REPORT FOR THE SAN JUAN RIVER RECOVERY IMPLEMENTATION PROGRAM

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EXECUTIVE SUMMARY

- Intensive mechanical removal must move to adjacent downstream reaches in an attempt to suppress movement and subsequent re-occupation into areas where removal efforts are currently being conducted

- Mechanical removal efforts corresponded with and overall reduction in mean total length and mass of channel catfish

- Catch rates of channel catfish in 2001 were significantly higher than those of 1999, which can be attributed to increased catch rates of juvenile channel catfish, possibly a bi-product of mechanical removal

- Mechanical removal of common carp has not resulted in any significant changes in capture rates or reductions in size class distribution but is proposed to continue

- Collection of young of year channel catfish and common carp was uncommon

- Preliminary mark/recapture data indicate that channel catfish readily utilized the non-selective fish ladder at Hogback Diversion to occupy upstream reaches

- Transplantation of channel catfish from the San Juan River to closed impoundments within the Basin is supported and investigation into the expansion of this program is highly recommended.

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INTRODUCTION

Non-native species and their interactions and subsequent impacts on native fish populations has long been a concern to fisheries biologists (Tyus and Saunders, 2000; Minckley, 1991). The establishment of these populations may negatively impact native fishes through direct competition for habitat and resources or by predation (Sigler, 1987). Alteration to riverine habitats by dam operations, water diversion and bank stabilization have all contributed to the establishment and spread of non-native fish, primarily channel catfish (*Ictalurus punctatus*) and common carp (*Cyprinus carpio*), in the San Juan River Basin (Brooks et al., 2000).

While many large bodied non-native fish species occur throughout the San Juan River, recent survey results show that the most abundant and widespread is the channel catfish (Ryden, 2000). The earliest report of channel catfish in the San Juan basin was 1957 (University of New Mexico, Museum of Southwestern Biology) but it is likely the species was present long prior to this. According to Jordan (1891), "It is thought that the lower San Juan and the Colorado would be well suited for the growth of the larger catfishes... It would be well to make a plant of these at Green River Station and one on the San Juan at Arboles". Channel catfish can occupy essentially all available habitat types on a year round basis, exhibit localized movement and larger individuals (>450mm TL) prey upon native fish (Brooks et al., 2000). This species survives within the San Juan river without substantial exploitation from humans (Smith, 2000).

The second most abundant large bodied non-native fish in the San Juan River is the common carp (Ryden, 2000). The first introductions in New Mexico occurred in 1883 from stock produced by the U.S. Fish Commission (Sublette et al., 1990). Like channel catfish, common carp can occupy a wide variety of habitats and due to their omnivorous feeding habits often constitute a large proportion of the total weight of fish present (Cooper, 1987). The common carp is often considered a pest species because it alters habitat through increased turbidity, uproots aquatic vegetation, feeds on the eggs of more desirable species and is not considered a favorable food fish in the United States (Sublette et al., 1990; Cooper, 1987).

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In addition to channel catfish and common carp, recent survey results revealed the presence of three lacustrine fish species including threadfin shad (*Dorosoma petenense*), walleye (*Stizostedion vitreum*) and striped bass (*Morone saxatilis*). The source of these fish is likely a result of the inundation of the waterfall at river mile (RM) 0.0, Lake Powell, in the spring of 1995 (Ryden, 2000). Since the initial collections of these species, the distribution and abundance of striped bass at various times throughout the year has increased and poses a serious concern to the recovery of native fishes in the San Juan River (Ryden, 2001).

Adult fish monitoring and research conducted from 1991-1997 revealed distinctive patterns in both size class distribution and relative abundance from upstream to downstream reaches. Ryden (2000) found that channel catfish collected in the furthermost upstream reaches, Geomorphic Reaches 6 and 5 (RM 180.0 - 131.0), as described by Bleisner and Lamarra (1999), were almost exclusively adults while downstream populations were predominantley juvenile fish. In addition, catch rates for channel catfish tended to be highest in Reaches 5 and 4 with mean catch rates declining to virtually no channel catfish in Reach 1 (RM 17.0 - 0.00).

Intensive mechanical removal efforts were focused from PNM Weir to Hogback Diversion (RM 167.5 - 159.0) because PNM Weir serves as a unique barrier to upstream emigration. Riverwide surveys conducted from 1991 to 1997 showed that of 1,712 channel catfish collected in Reach 6, only ten (0.6%) were collected upstream of PNM Weir (Ryden, 2000). In addition, channel catfish collected in this reach were almost exclusively large adult fish (> 300 mm TL). It was also found that common carp capture rates upstream of the diversion were at least half of those downstream. This barrier to upstream movement provides a unique situation to evaluate the efficacy of intensive mechanical removal of large bodied non-native fishes.

During 1991-1997, non-native species studies on the San Juan river focused on the identification of negative impacts to native fishes. Research was conducted to characterize the distribution and abundance of non-natives in main channel habitats, seasonal movement of both channel catfish and common carp, the food habits of non-native fishes, primarily channel catfish; the overlap of

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resource use between native and non-native fish species and the relation of these findings to differing flow regimes (Brooks et al., 2000). Throughout this study, all non-native fishes were the target of removal efforts with emphasis placed on the abundant channel catfish. We report upon the results of mechanical removal efforts for large bodied non-native fishes, primarily channel catfish and common carp, collected from 1999-2001.

The study objectives were as follows: 1) Continue data collection and mechanical removal of non-native fish species during main channel adult rare fish monitoring efforts; 2) Evaluate capture rate and length frequency distribution data for non-native species to determine the effects of mechanical removal on abundance and distribution patterns; 3) Continue, refine and expand the program for mechanical removal and transplantation of channel catfish; 4) Monitor the influx of lacustrine non-native fish species (e.g. striped bass and walleye) into the San Juan River upstream of Lake Powell, Utah and record predative impacts via stomach content analysis; 5) Continue data integration efforts for input into the *Program Evaluation Report* and revised *Long Range Plan*.

STUDY AREA

Non-native fishes were removed from the San Juan River, Colorado, New Mexico, Utah; including accessible secondary channels from Farmington, New Mexico (Animas River confluence [RM 180.0]) downstream to Clay Hill's Landing (RM 2.9), Utah. Repeated intensive removal efforts were conducted in New Mexico from PNM Weir (RM 167.5) downstream to Hogback Diversion (RM 159).

METHODS

Sampling conducted during adult monitoring trips from 1999-2001 followed the same protocols as previous years (Ryden, 2000). Fish were collected using raft mounted electrofishers. Each raft consisted of one rower and one netter and floated perpendicular to the shoreline netting all fish seen. Sampling was conducted in one RM increments. At the end of each RM, all fish collected

were enumerated by species and size class. At the end of every fifth mile, or designated mile, fishes were measured to the nearest millimeter (mm) for total and standard lengths and weighed to the nearest 5 grams (g) for mass. All non-native fishes were removed from the river.

Sampling conducted from PNM Weir to Hogback Diversion followed similar protocol. A support raft was used both to collect any non-native fish that surfaced behind the shocking rafts and to serve as a holding unit for transporting live fish. All non-native fishes or a representative sub-sample were measured (nearest 1 mm) for total and standard lengths and weighed (nearest 5 g) for mass. All non-native fish were removed from the river. When possible, channel catfish were held for transplantation. Channel catfish were kept in live wells treated with salt at 189 grams/37.85 liters of water and stress coat at 10 milliliters/37.85 liters of water. A battery powered aeration system or compressed oxygen was used for circulation and aeration. Channel catfish were transported from the San Juan River in distribution trucks provided by the New Mexico Department of Game and Fish and the Navajo Nation Department of Fish and Wildlife to closed impoundments located within the drainage.

The capture rates (fish/hour of electrofishing) of each common carp and channel catfish size class was calculated using all available capture data. Capture rates between years were compared using a Kruskal-Wallis non-parametric rank test (Zar, 1999; SPSS Inc., 1999). A rank test (nonparametric statistic) was used since capture rate data were not normally distributed and data transformations were unsuccessful in achieving normality (Legendre and Legendre, 1998; Zar, 1999). Multiple pairwise comparisons were made for all reaches combined and for individual reaches where sample size was adequate for comparison among years.

Mean common carp and channel catfish TL and weight were determined for all years using all available length data collected during fall monitoring trips. Annual means were compared using Kruskal-Wallis non-parametric rank test (Zar, 1999; SPSS Inc., 1999). A rank test (nonparametric statistic) was used since capture rate data were not normally distributed and data transformations were unsuccessful in achieving normality (Legendre and Legendre, 1998; Zar,

1999). Multiple pairwise comparisons were made for all reaches combined and for individual reaches where sample size was adequate for comparison among years. Due to separate more intensified sampling, the PNM Weir to Hogback Diversion reach was analyzed independently from the monitoring trips.

RESULTS

From 1999 to 2001 a total of 18,260 channel catfish and 9,547 common carp were removed from Geomorphic Reaches 6-1 (RM 180.0 - 0.00). Total effort fluctuated during years with 1999 having the least amount of effort (158.88 hours) and 2001 the most (212.05 hours). The following are results of comparisons of catch rates between years for each of the six geomorphic reaches.

Channel Catfish Catch Rates

Channel catfish catch rates varied little between years during the three year study period. Total effort and overall numbers of channel catfish collected annually have increased with each subsequent year of sampling since 1998 (Table 1). Significant increase ($p < 0.05$) in overall catch rates was observed between 1998 and all other subsequent years (Table 2, Figure 1). Following the observed initial increase in 1999, catch rates riverwide remained relatively constant with no significant differences among years.

Catch rates within Reach 6 (RM 180.0 - 155.0), a portion of which where intensive mechanical removal was conducted (RM 167.9 to RM 159.0), fluctuated little between years. Juvenile catch rates remained low with 1999 yielding the highest (7.30 channel catfish/hour) of any other year (Table 3, Figure 2). No significant differences among catch rates of juvenile channel catfish were observed in Reach 6 (Table A-9) Similar to juvenile channel catfish, catch rates of adult channel catfish varied between years. Catch rates appeared to be decreasing from 1998 to 2000 however, 2001 marked a large increase in catch rates of adult fish (Table 3, Figure 2). Again, although this increase was documented no significant difference was observed (Table A-16).

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Table 1. Total number of channel catfish (*Ictalurus punctatus*) and common carp (*Cyprinus carpio*) collected during main channel electrofishing surveys conducted in the spring/fall of each year, 1998-2001.

Species	Year	Young of Year	Juvenile	Adult	Total	Total Effort (Hours)
Channel catfish	1998	63	2738	1992	4793	235.12
	1999	114	2798	2224	5136	158.88
	2000	112	4304	1903	6319	178.06
	2001	110	4435	2269	6814	212.05
	Total	399	14275	8388	23062	784.10
	% of total catch	(1.73%)	(61.90%)	(36.37%)		
Common carp	1998	1	51	3308	3360	-
	1999	0	13	3074	3087	-
	2000	99	235	2430	2764	-
	2001	0	98	3508	3606	-
	Total	100	397	12320	12817	-
	% of total catch	(0.78%)	(3.10%)	(96.12%)		

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Table 2. Capture rates for channel catfish (*Ictalurus punctatus*) and common carp (*Cyprinus carpio*) collected during main channel electrofishing surveys conducted in the spring/fall of each year, 1998-2001.

Species	Year	Fish per hour of electrofishing		
		Juvenile	Adult	Total
Channel catfish	1998	11.56	8.23	20.07
	1999	19.62	13.49	33.89
	2000	23.72	10.59	34.91
	2001	21.27	11.96	33.63
	Total	18.28	10.67	29.43
Common carp	1998	0.20	13.64	13.84
	1999	0.10	18.41	18.51
	2000	1.44	14.13	16.14
	2001	0.55	15.42	15.97
	Total	0.56	15.08	15.77

Geomorphic Reach 5 (RM 155.0 - 131.0) also had high variability in overall catch rates between years. Overall catch rates of channel catfish were significantly higher in 2000 than any other year (Table A-3, Figure 2). In 1999, 39.95 channel catfish/hour were collected followed by a rate of 61.20 channel catfish/hour in 2000 (Table 3). Juvenile channel catfish comprised the bulk of the 1999 to 2000 increase (Figure 2). Trends from 1998 to 2001 for all life stages combined show a general upward trend in both Reach 6 and Reach 5.

Similar to adjacent upstream reaches, Reach 4 (RM 131.0 - 106.0) and Reach 3 (RM 106.0 - 68.0) displayed higher overall catch rates for channel catfish in 2001 than 1998. Within each of these reaches, catch rates from 1999 to 2001 were significantly higher than those observed in 1998 (Tables A-4, A-5; Figure 3).

In Reach 2 (RM 68.0 - 17.0), overall catch rates from 1999 to 2001 have remained relatively higher than those observed in 1998. A significant increase in juvenile channel catfish catch rates was observed from 1998 to 1999 and have remained high in subsequent years (Table A-13, Figures 4 and 5). Adult catch rates have varied little from 1999 to 2001 but still remain higher than those observed in 1998. Catch rates in Reach 1 (RM 17.0 - 0.00) have remained the lowest of any other reach. In 2001, catch rates were significantly higher than the previous two years (Table A-7, Figure 4), primarily a result of an increase in the number of juvenile fish collected.

Table 3. Mean catch rates (fish per hour of electrofishing) for channel catfish collected during main channel electrofishing in the San Juan River 1998-2001. Data are presented by Geomorphic Reach and separated by size class for each of the years sampled.

Reach	Young of Year				Juvenile				Adult				Total			
	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001
6	0.00	0.00	0.00	0.00	2.73	7.30	4.06	5.00	14.92	11.53	8.79	24.10	17.65	18.82	12.79	29.09
5	0.05	0.00	0.00	0.05	11.01	11.72	37.40	13.88	17.41	28.22	23.80	23.56	28.46	39.95	61.20	37.49
4	0.30	0.38	0.61	0.82	14.60	18.69	20.53	18.35	5.93	13.15	12.54	10.75	20.82	32.22	33.68	29.92
3	0.38	0.19	0.74	0.50	18.09	18.93	19.36	25.24	3.92	9.56	6.58	7.51	22.39	28.80	26.68	33.26
2	0.46	3.14	1.26	0.31	8.50	39.02	31.15	35.62	2.97	7.29	4.81	5.07	11.95	49.45	37.21	41.00
1	0.32	0.00	0.33	0.13	0.70	5.78	2.36	8.55	0.81	1.07	1.12	3.05	1.82	6.85	3.81	11.72
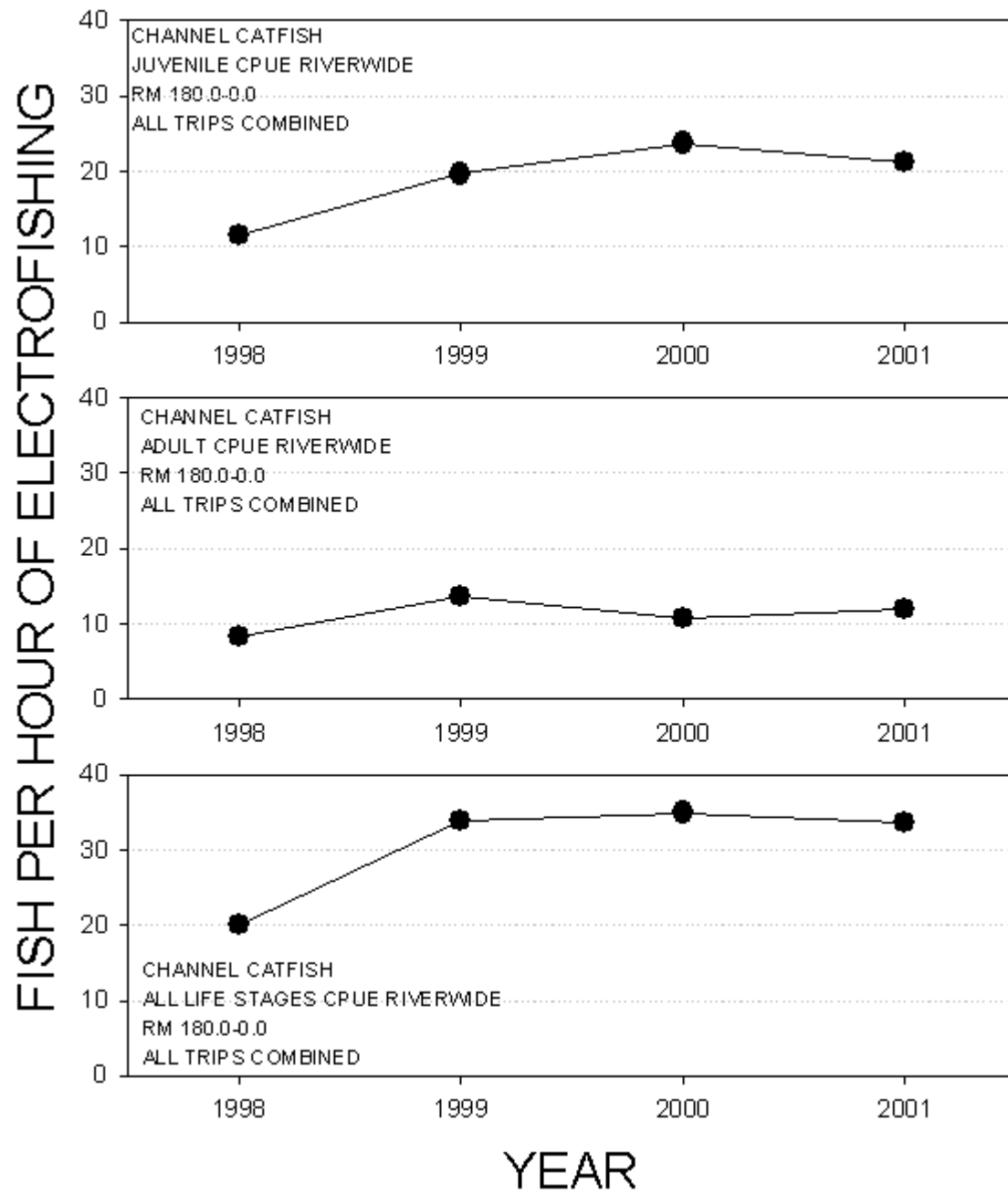
Figure 1. Capture rates (fish per hour of electrofishing) of two size classes and all life stages combined of channel catfish collected riverwide (RM 180.0 - 0.00) in the San Juan River, 1998-2001. Young of year capture rates are not presented independently due to low numbers collected but are included in all life stages combined.
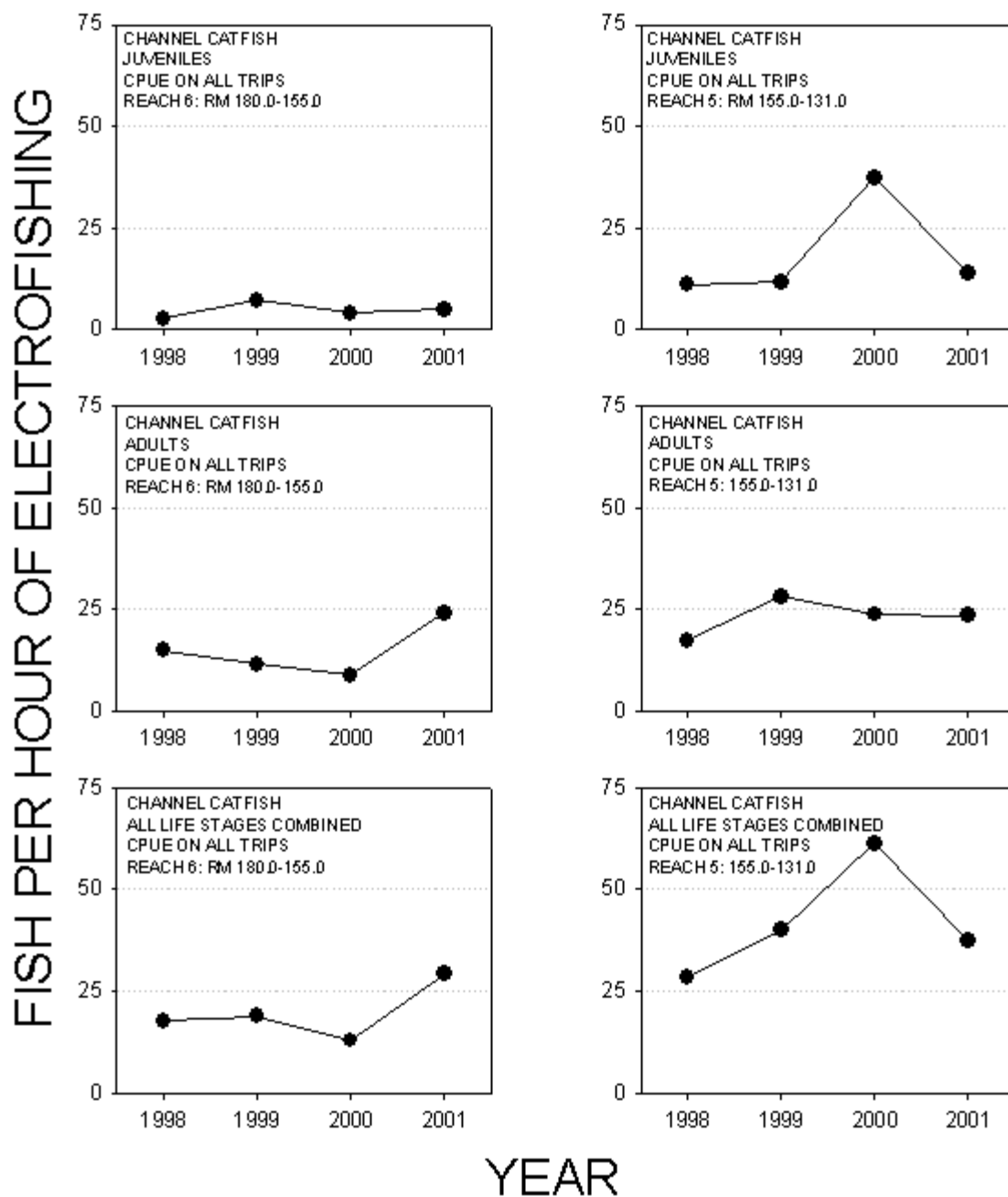
Figure 2. Capture rates (fish per hour of electrofishing) of channel catfish collected in Geomorphic Reach 6 (RM 180.0 - 155.0) and Reach 5 (RM 155.0 - 131.0) of the San Juan River, 1998-2001.

Figure 3. Capture rates (fish per hour of electrofishing) of channel catfish collected in Geomorphic Reach 4 (RM 131.0 - 106.0) and Reach 3 (RM 106.0 - 68.0) of the San Juan River, 1998-2001.

Figure 4. Capture rates (fish per hour of electrofishing) of channel catfish collected in Geomorphic Reach 2 (RM 68.0 - 17.0) and Reach 1 (RM 17.0 - 0.00) of the San Juan River, 1998-2001.
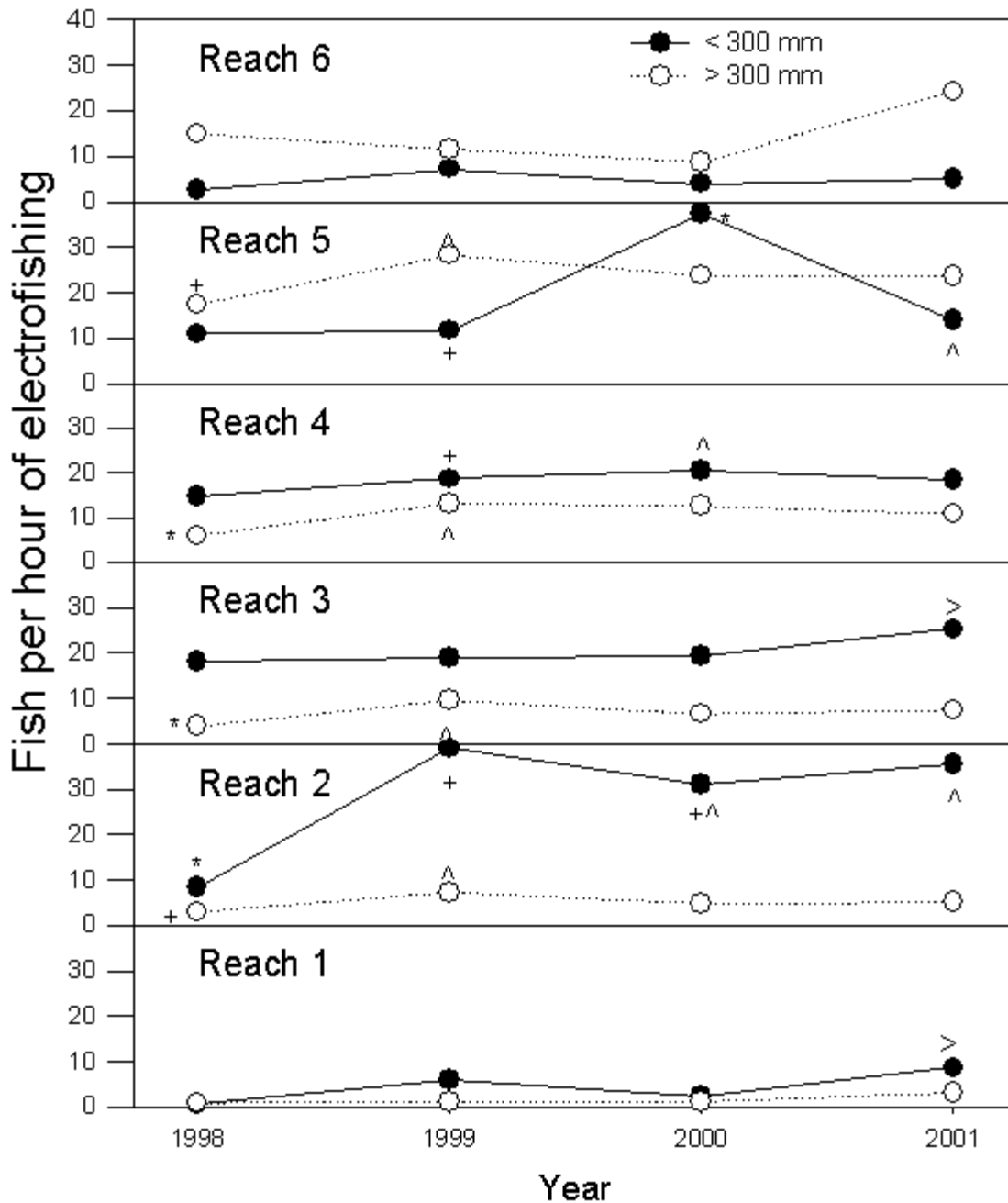
Figure 5. Capture rates by year and geomorphic reach of two size classes of channel catfish collected during main channel electrofishing efforts on the San Juan River, 1998-2001. Symbols represent overall significant differences between years (* = significantly different than all other years; ^ = significantly different than previous year; + = significantly different than following year; > = significantly different than 1998 and 1999). Significance determined by a Kruskal-Wallis non-parametric rank test using multiple pairwise comparisons of ranks.

Channel catfish Size Structure

Channel catfish mean TL varied little among years within the study period. Mean TL in 1999 was 257.92 ± 99.71 mm with over 15% of all fish measured falling within the 240-280 mm range. 1999 mean TL was significantly lower (Table C-1) and size distribution was more normal (Figure 6) than in 1998 (291.11 ± 28.04). Mean total length increased following 1999 but a large percentage of fish measured were within the 160 - 200 mm range. Although mean measurements have increased from 1999-2001 it appears that a shift to smaller sized individuals can be observed (Figure 6). This trend is evident with approximately 15% of all channel catfish collected in 2000 falling within the 160 - 200 mm and 15% collected in 2001 falling within the 120 - 160 mm range. Since 1999, fewer large adult (> 500 mm) channel catfish have been collected riverwide (Figure 6).

Reach by reach comparison of mean TL throughout the study period exhibited much of the same trend that Ryden (2000) observed. Larger adult channel catfish are typically more abundant in the furthermost upstream reaches while juveniles dominate downstream populations (Figure 7). From 1998 to 2001, channel catfish collected in Reach 6 were the largest of any other reach with a mean TL of 393.21mm. Mean TL in both Reach 6 and Reach 5 were nearly identical with the mean in 1999 being significantly lower than both 2000 and 2001 (Table C-2, Table 3-3). Mean TL in Reach 4 was significantly higher in 2000 than any other year during the study period (Table C-4, Figure 7) with a mean of 325.33 mm. Few differences were observed during the study period in Reaches 3-1, likely a factor of fewer channel catfish collected within these lower reaches. In 1998, Reach 1 exhibited the highest mean TL of any of the four years sampled and since initially declining in 1999 mean TL for this reach has steadily increased to end in 2001 with the fourth highest mean total length riverwide (Figure 7).
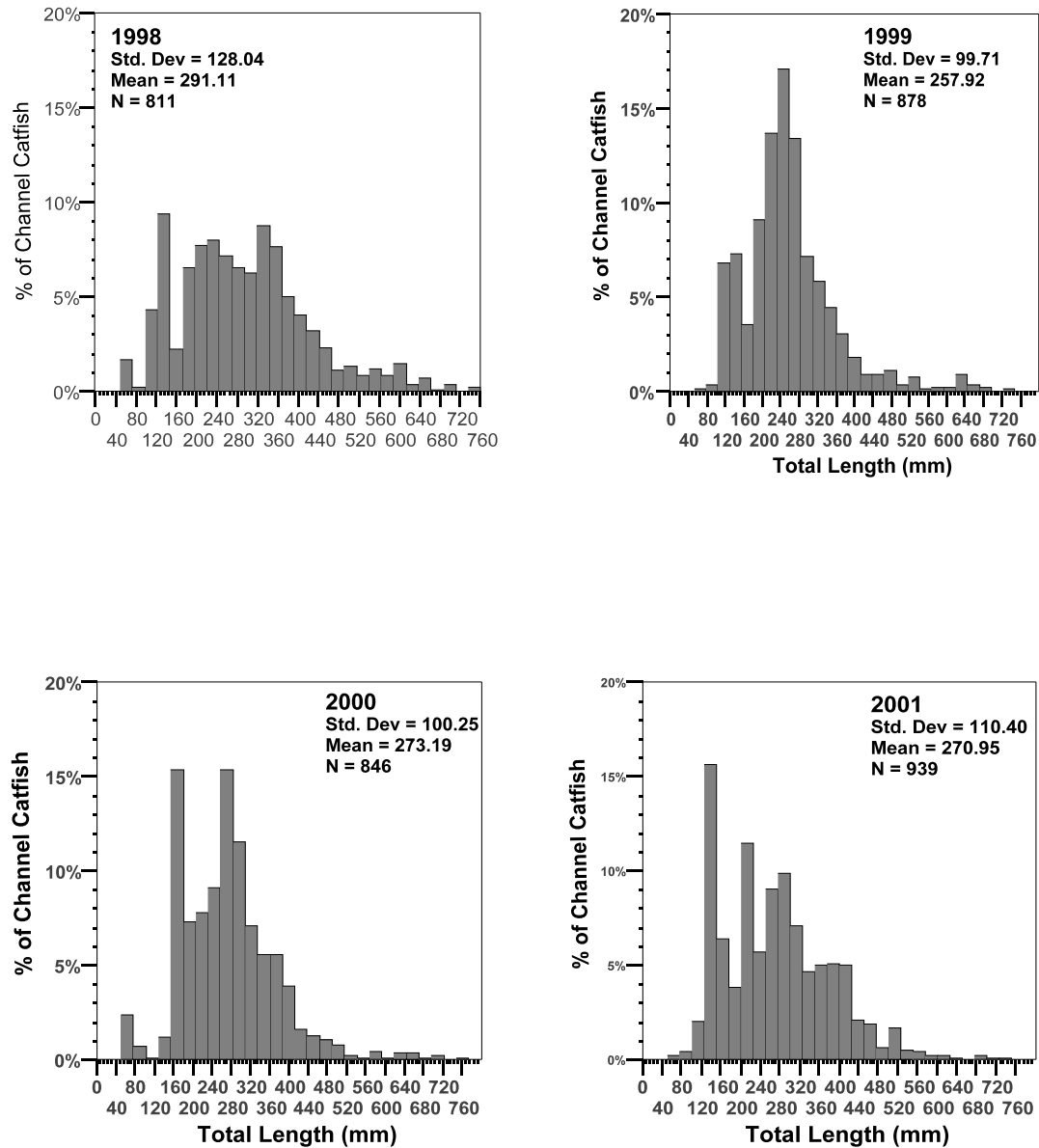
Figure 6. Length frequency histograms of channel catfish collected during fall monitoring trips on the San Juan River, 1998-2001.
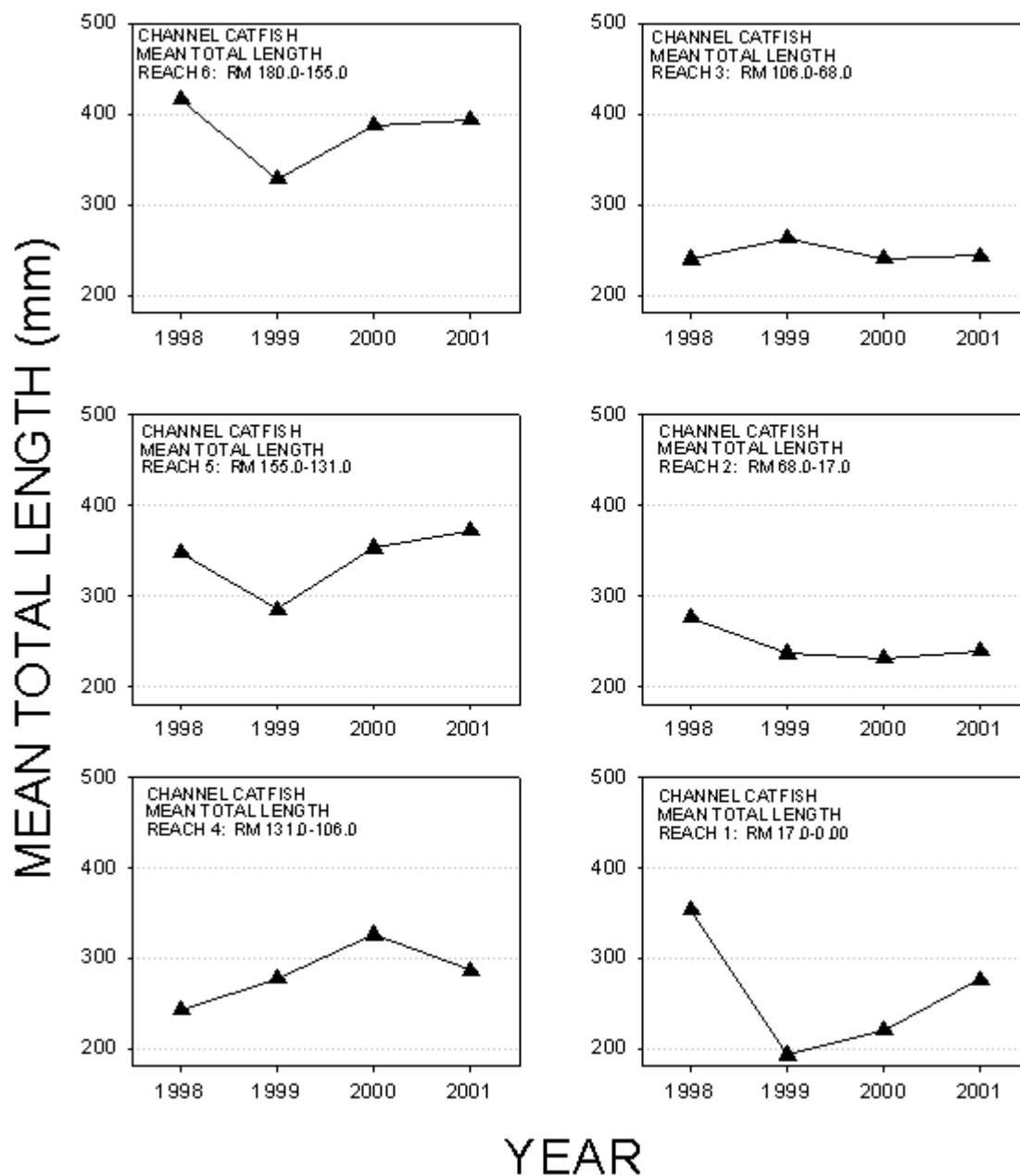
Figure 7. Mean total lengths (mm) of channel catfish collected in each of six Geomorphic Reaches of the San Juan River, 1998-2001.

Common Carp Catch Rates

Long term trends in common carp catch rates were not readily visible throughout the study period. In 1999, catch rates for common carp riverwide were the highest of the study period but were not significantly different than 2000 or 2001 (Table 2, Table C-1, Figure 8). Lowest overall catch rates for common carp were observed in 1998 (Tables 2, B-1; Figure 8).

Common carp catch rates varied from year to year with no distinct trend from 1999-2001. Overall, 2001 exhibited the lowest catch rates between years but was not statistically different ($p < 0.05$) than previous years. As observed in past studies, common carp catch rates were dominated by adult individuals with few juvenile or young of year common carp collected ($< 5\%$ of total common carp catch). In spite of this, juvenile catch rates for common carp were significantly higher (Table B-8, Figure 8) in 2000 than any other year and are most likely a result of an unprecedented amount of juvenile common carp collected in Reach 6 (Figure 9 and Figure 13).

Common Carp Size Structure

Common carp size class distribution varied little among years and catch was dominated by large adult fish with relatively little to no juvenile and young of year fish captured. With exception to 2000, length frequency histograms for common carp revealed a narrow distribution of size classes (Figure 12). In 2000, an increase of common carp between 60 - 100 mm TL were collected representing approximately 16% of all common carp measured. This increase in juvenile catch rates corresponds with the lowest mean TL (364.48 mm) between 1998-2001 (Figure 12).
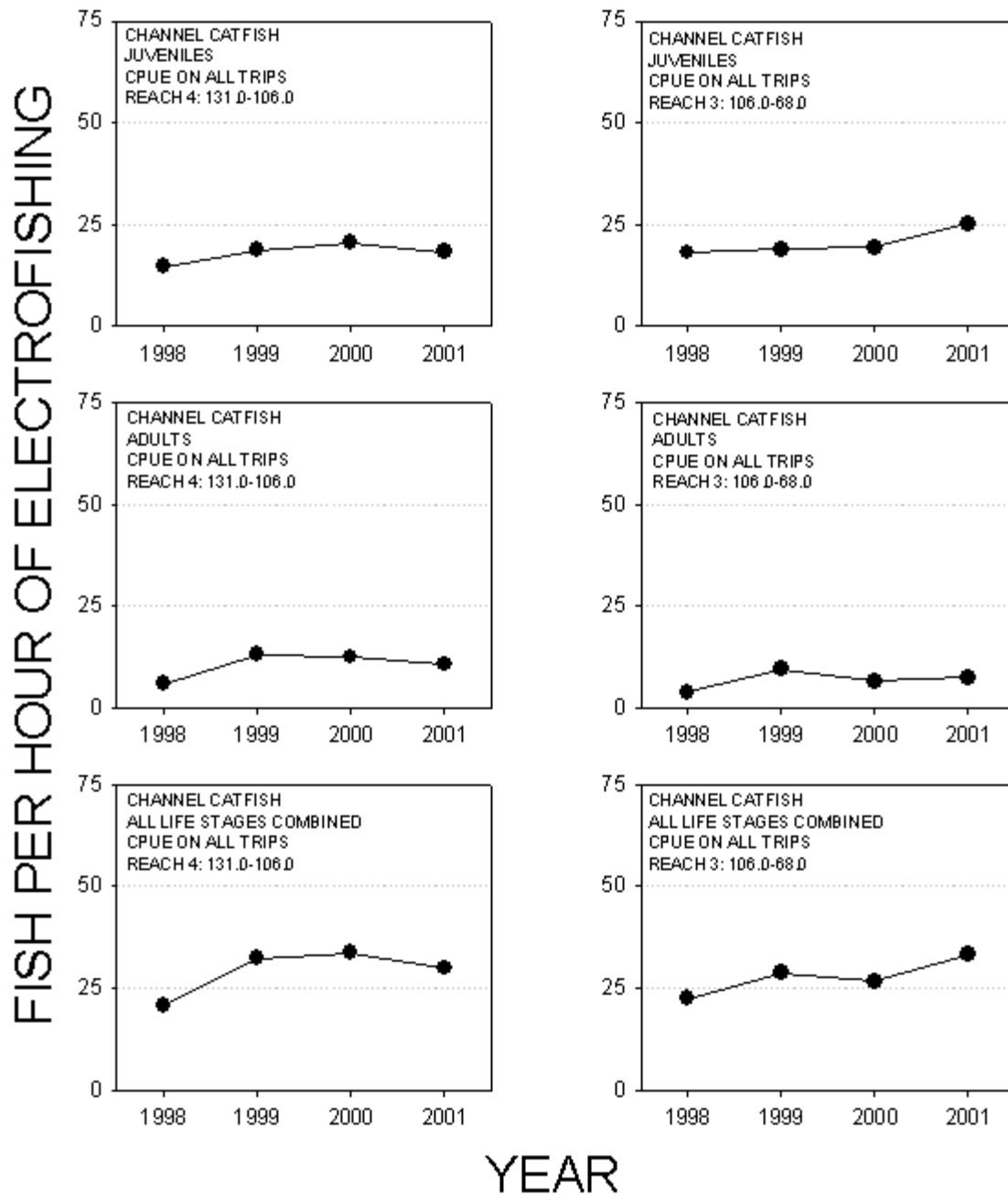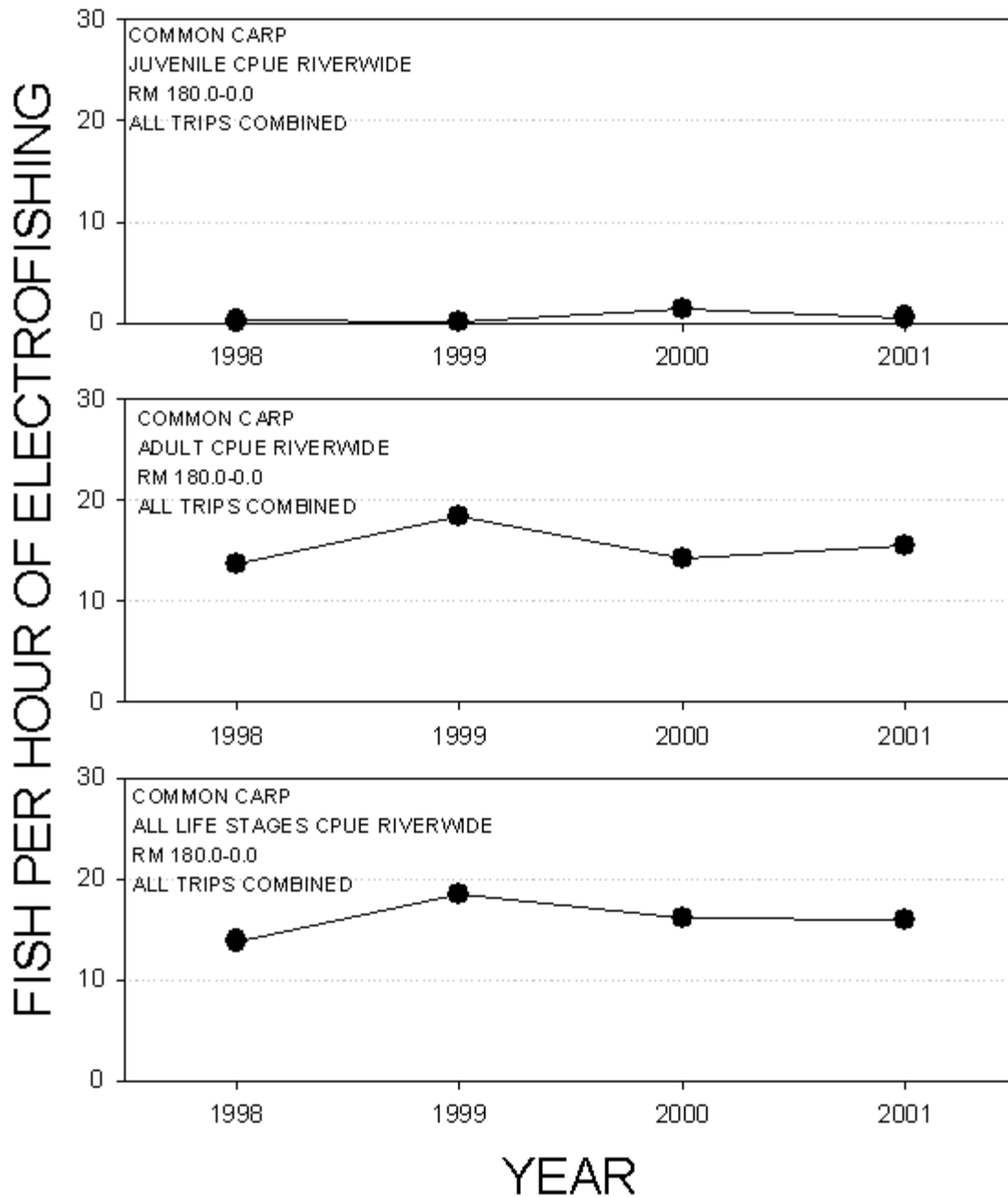
Figure 8. Capture rates (fish per hour of electrofishing) of two size classes and all life stages combined of common carp collected riverwide (RM 180.0 - 0.00) in the San Juan River, 1998-2001. Young of year capture rates are not presented independently due to low numbers collected but are included in all life stages combined.
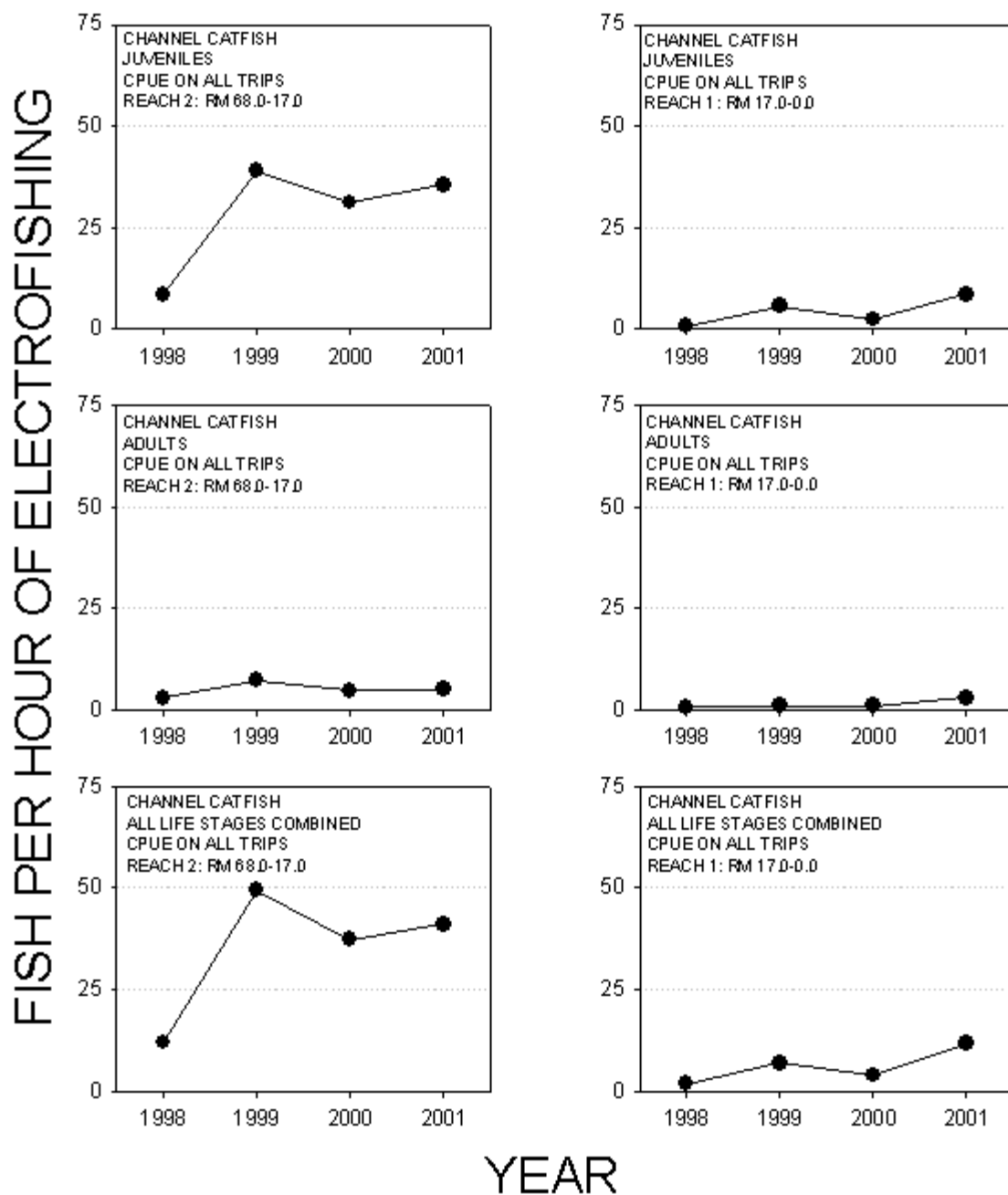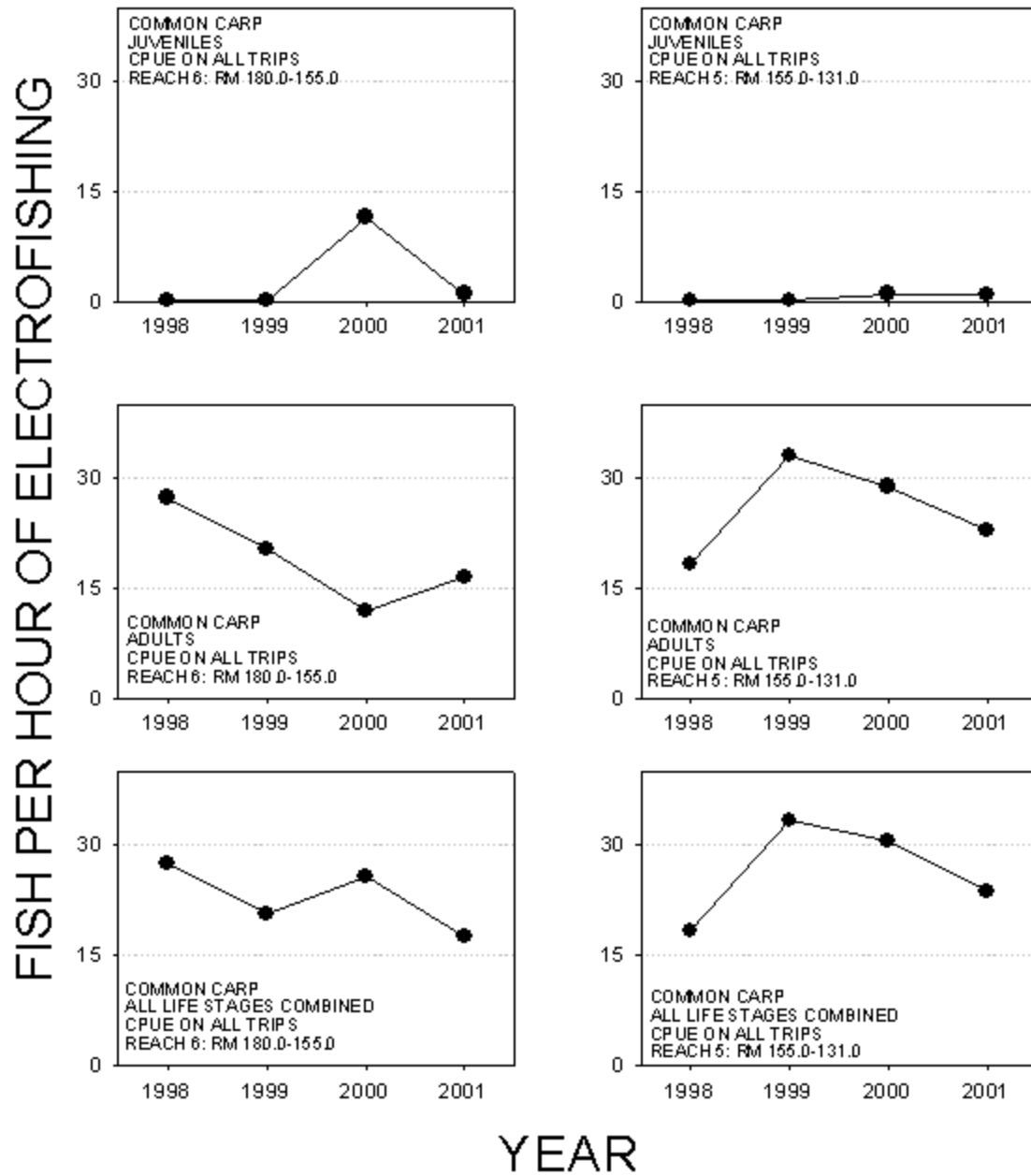
Figure 9. Capture rates (fish per hour of electrofishing) of common carp collected in Geomorphic Reach 6 (RM 180.0 - 155.0) and Reach 5 (RM 155.0 - 131.0) of the San Juan River, 1998-2001.
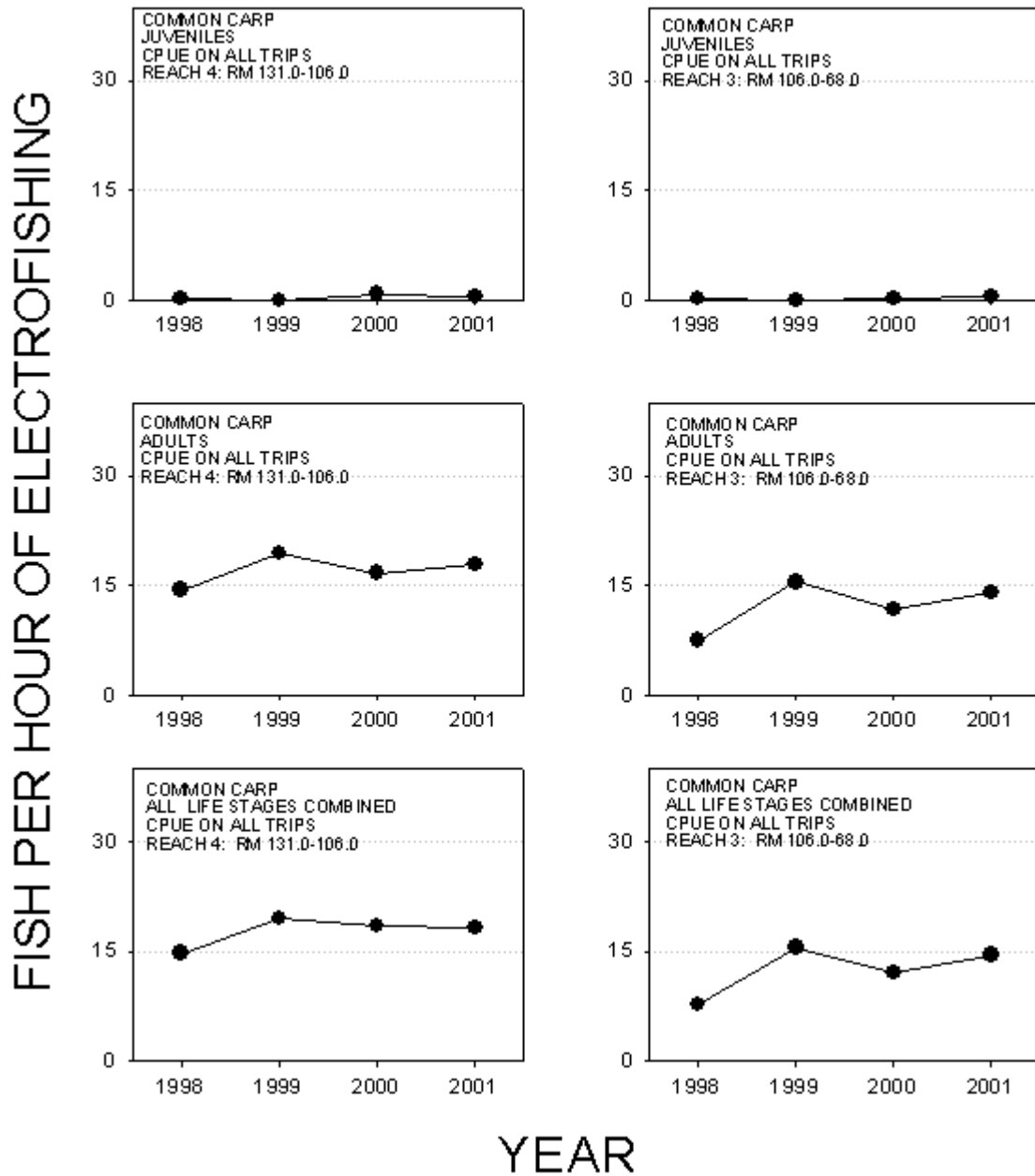
Figure 10. Capture rates (fish per hour of electrofishing) of common carp collected in Geomorphic Reach 4 (RM 131.0 - 106.0) and Reach 3 (RM 106.0 - 68.0) of the San Juan River, 1998-2001.
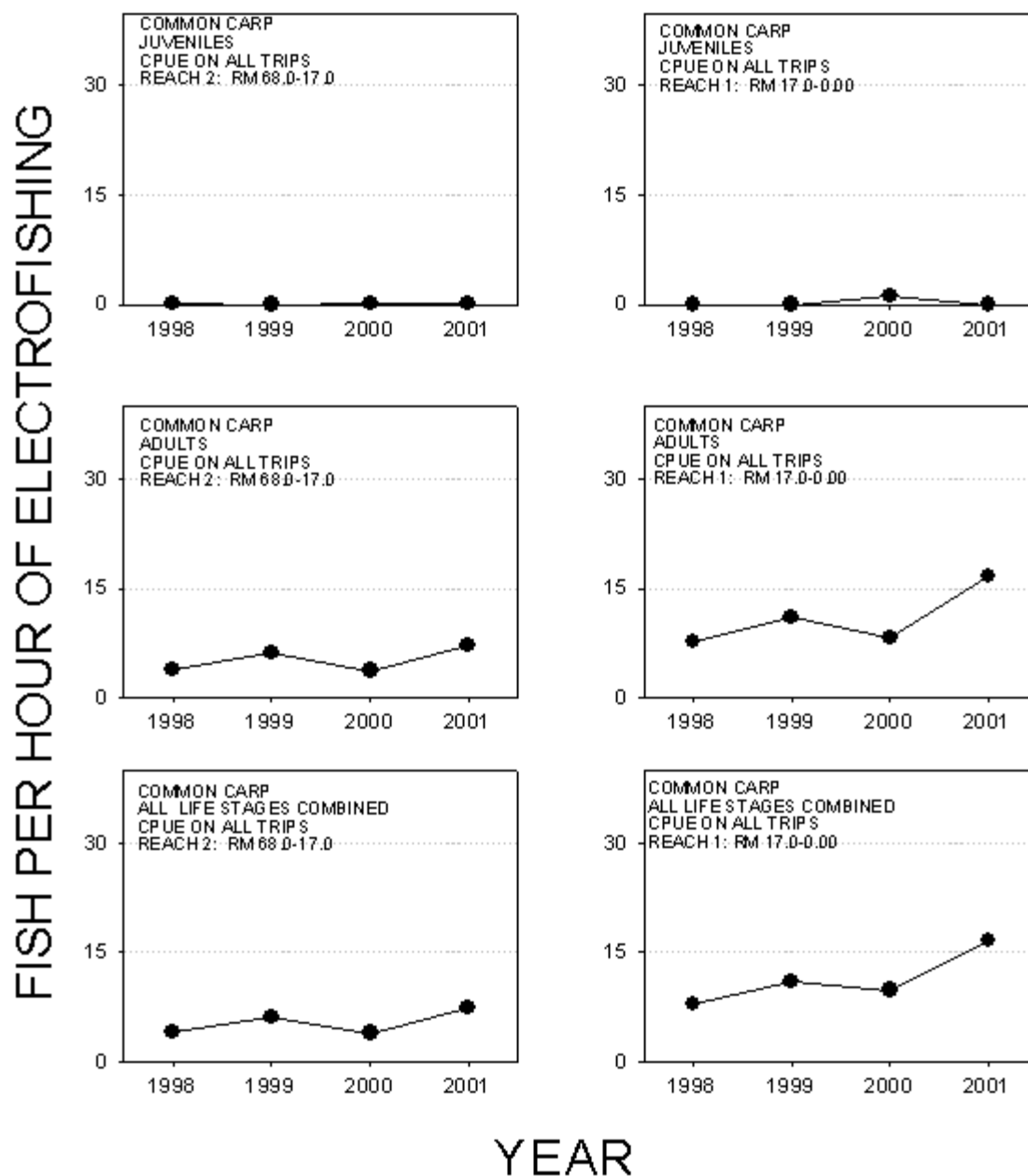
Figure 11 . Capture rates (fish per hour of electrofishing) of common carp collected in Geomorphic Reach 2 (RM 68.0 - 17.0) and Reach 1 (RM 17.0 - 0.00) of the San Juan River, 1998-2001.
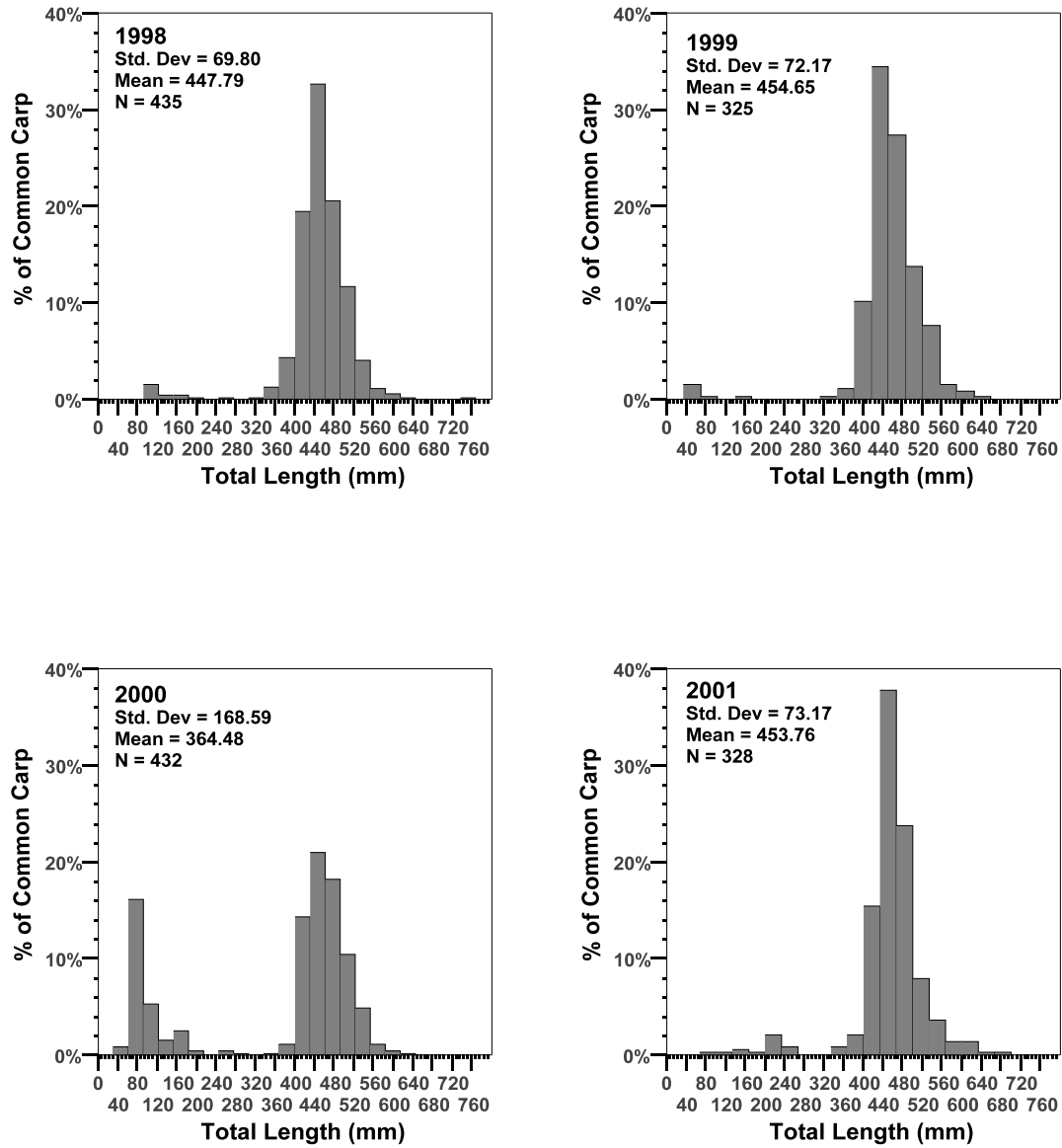
Figure 12. Length frequency histograms of common carp collected during fall monitoring trips on the San Juan River, 1998-2001.
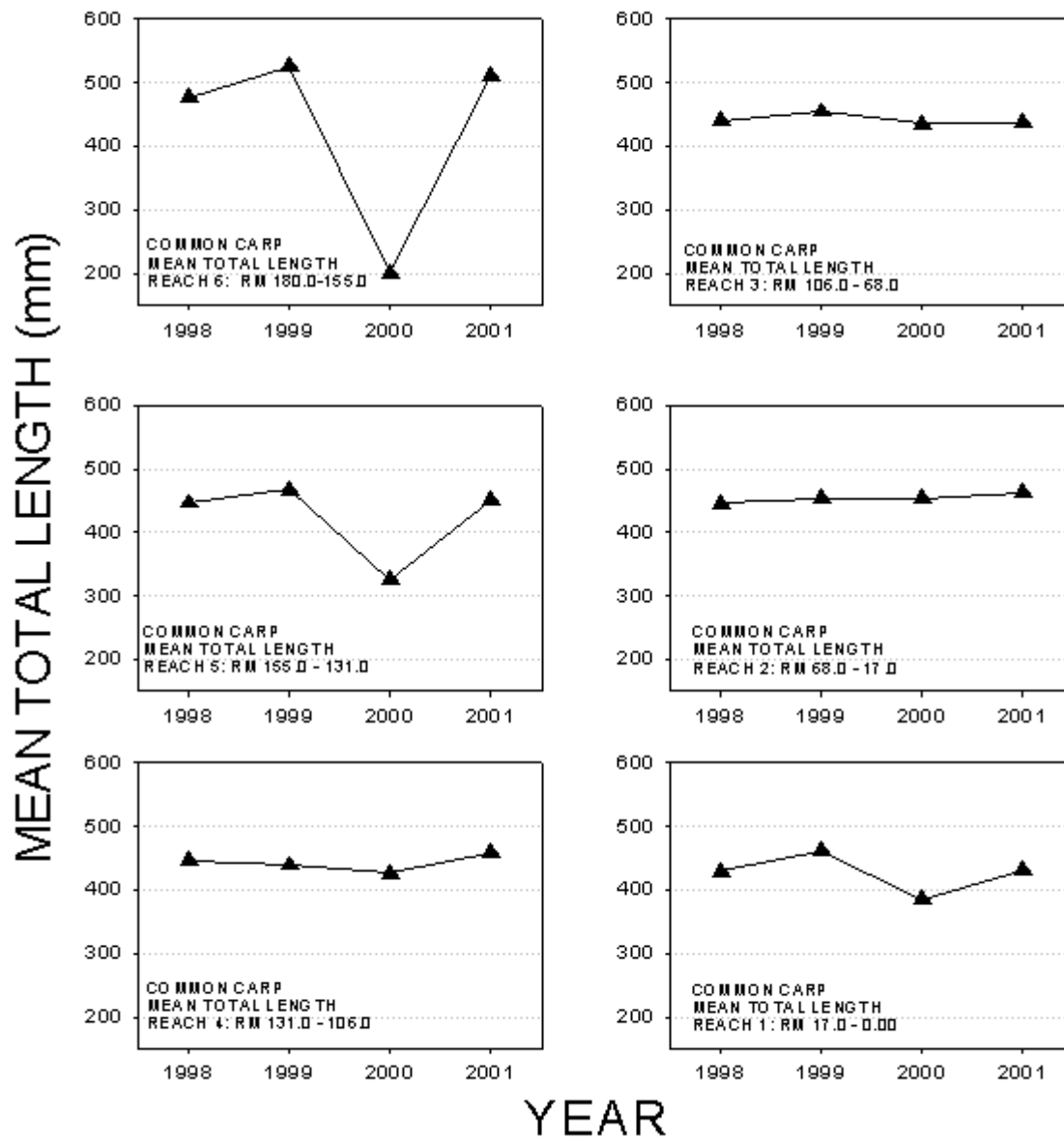
Figure 13. Mean total lengths (mm) of common carp collected in each of six Geomorphic Reaches of the San Juan River, 1998-2001.

Mechanical Removal from PNM Weir to Hogback Diversion (RM 167.5 - 159.0), 1998-2000

Removal of common carp and channel catfish began in this portion of Reach 6 in 1998. Baited hoop nets yielded 177 channel catfish in 99 net days for capture rates of 1.78 fish/day of sampling. Mean total length of channel catfish was 239.5 mm. Due to the extremely low capture rates, it was determined that electrofishing would be a more effective means of mechanical removal on the San Juan River.

A total of 454 channel catfish were collected in three days of electrofishing in 1999. Five days of sampling in 2000 yielded 1,773. Catch rates increased from 0.88 fish/min in 1999 to 1.04 fish/min. in 2000. Channel catfish mean total length significantly ($p < 0.05$) decreased between 1999 to 2000 from 487.06 ± 87.44 mm to 405.25 ± 73.98. TL ranged from 321-742 in 1999 and 244-725 mm in 2000 (Figure 14).

Within this same reach, a total of 1,524 common carp were removed in three days of sampling in 1999 and 955 in 2000. Catch rates were 3.0 fish/min in 1999 and 0.69 fish/min in 2000. The analysis detected a significant increase in mean total length from 467.24 ± 43.23 in 1999 to 476.93 ± 41.99 mm in 2000 (Figure 14). With so few trips and the varying amount of effort between years, these data have been analyzed independently to those of 2001.

Intensive Mechanical Removal from PNM Weir to Hogback Diversion, 2001.

A total of 10 trips were conducted from February to November 2001 with a total of 178 hours of electrofishing. Sampling yielded a total of 4,024 channel catfish and 3,074 common carp. Other non-native species collected included black bullhead (*Ameiurus melas*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), brown trout (*Salmo trutta*) and rainbow trout (*Oncorhyncus mykiss*).

The initial sampling trip of the year, 2001 February 20-22, yielded the second most channel catfish collected and the third highest catch rates over the 10 sampling trips (Table 4). Declining distribution was observed over six sampling trips prior to spring runoff with a total of 1,340 individuals removed. In the four remaining trips (July, August, September and November) the number of channel catfish removed doubled (n = 2,689).

The three highest catch rates observed occurred when stream discharge was < 900 cubic feet per second (as recorded at USGS gauging station #09365000 [2.3 RM upstream of La Plata confluence]) and once again increased once spring runoff receded. Comparisons between discharge and channel catfish capture rates exhibited a significant negative correlation, r = -0.782, p = 0.008 (Figure 15). Although discharge may account for the seasonal variability in catch rates observed, various factors including air and water temperatures, turbidity and conductivity and seasonal movement patterns of channel catfish may play significant roles in determining sampling efficacy as well.

Mean channel catfish TL decreased throughout sampling in 2001 (Table 4). Mean TL ranged from 447.06 mm to 363.01 mm with a yearly mean for all trips combined of 396.48 mm. Channel catfish less than 400 mm represented over half of all that were measured (55.6%). Only 14.7% were over 500 mm, while 6% were less than 300 mm or considered juveniles (Figure 14). Of these juvenile fish, 76.0% were collected during September. No young of year (YOY) fish were collected. The total length frequency histogram showed a normal distribution with a range of 141 to 730 mm (Figure 14). Mean TL of channel catfish in 2001 was the lowest from 1999 to 2001.
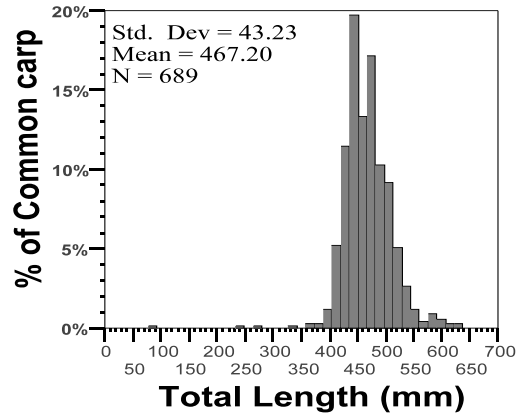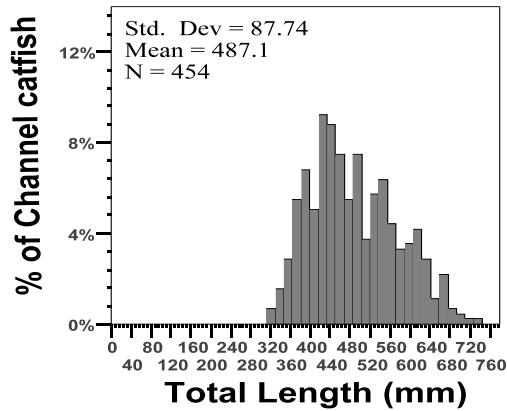
1999

2000
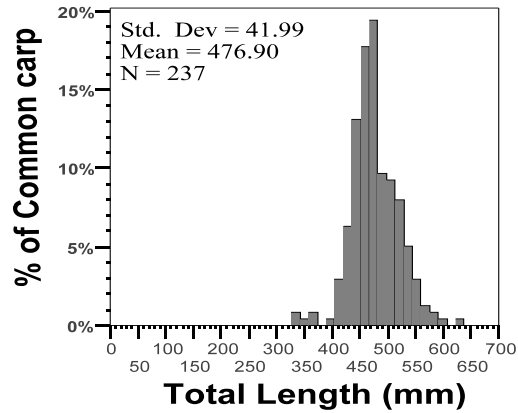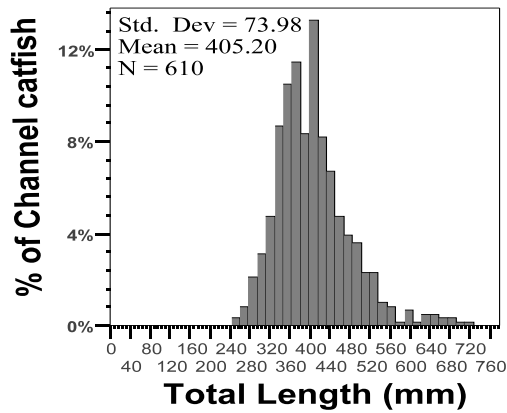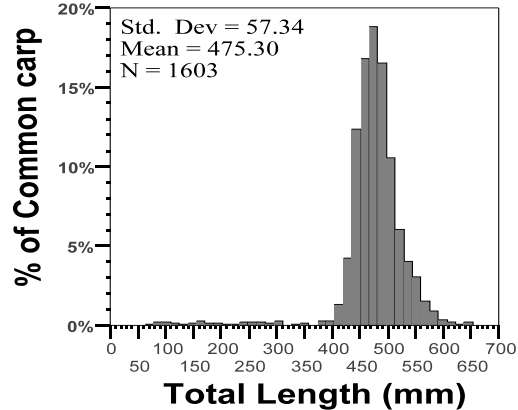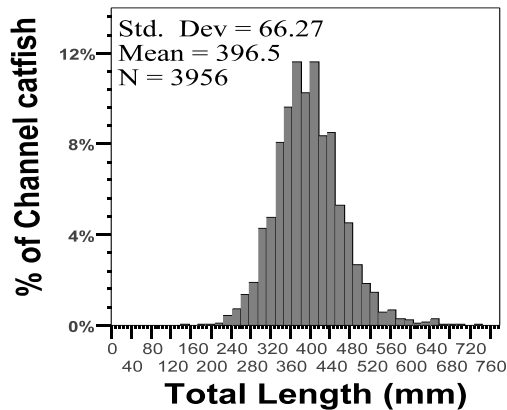
2001

Figure 14. Length frequency histograms of channel catfish collected from PNM Weir to Hogback Diversion in the San Juan River, 1999-2001.

Table 4. Comparison of catch rates (fish/min), total effort (min), mean total length (mm), standard length(mm) and mass (g) of channel catfish collected between PNM Weir and Hogback Diversion on 10 separate sampling trips during 2001.

Trip	Number of Fish	Flow (ft³/s)	Tot. Effort (hours)	Mean TL (mm)	Mean SL (mm)	Mean Mass (g)	CPUE (fish/hour)
20-22 Feb 2001	760	870	29.24	427.84	352.14	864.19	26.00
13-15 Mar 2001	280	1,050	25.08	418.89	339.68	790.08	11.16
26-28 Mar 2001	79	1,800	16.46	418.81	339.57	763.45	4.80
10-12 Apr 2001	97	1,250	18.17	434.22	351.82	768.44	5.34
24-26 Apr 2001	48	1,700	15.80	447.06	361.23	998.54	3.04
8-10 May 2001	76	2,500	14.00	417.09	336.08	709.30	5.43
10-12 July 2001	228	1,000	18.47	363.01	286.58	480.85	12.34
14-15 Aug 2001	107	2,650	10.54	371.83	294.50	563.79	10.15
11-13 Sept 2001	1,712	690	18.20	375.32	300.37	586.26	94.07
6-7 Nov 2001	637	650	12.11	406.53	328.33	688.56	52.60
Totals	**4,024**	**n/a**	**178.05**	**396.48**	**319.91**	**678.46**	**22.60**
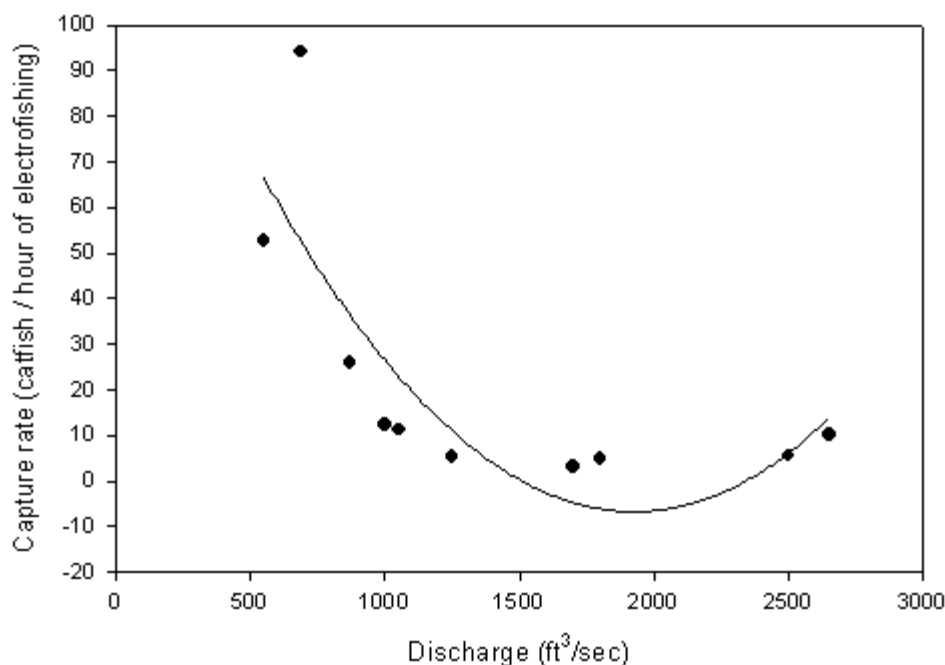
Figure 15. Significant negative correlation observed (r = -0.782; p = 0.008) between discharge and capture rates of channel catfish collected from PNM Weir to Hogback Diversion, 2001.

Similar to channel catfish, capture rates of common carp were the highest when discharge was < 900 cfs. The initial sampling trip yielded 35.7% of all common carp collected, while the four trips post spring runoff yielded 39.7% (n = 1,220). Again, a significant negative correlation, r = -0.733, p = 0.016; between discharge and capture rates was observed (Figure 16).

Similar to previous years of sampling in this reach and riverwide, common carp lengths varied little between years. Length frequency histograms showed a narrow TL range (Figure 14). In 2001, 2.8% of all common carp measured (n = 45) were ≤ 400 mm TL and 55.4% (n = 888) ranged from 481 to 520 mm TL. Mean total length generally decreased with each successive trip to end with a 10 trip mean of 475.35 mm (Table 5). Common carp total lengths ranged from 72 to 650 mm TL. No YOY common carp were collected in 2001.

Table 5.   Comparison of catch rates (fish/min), total effort (min), mean total length (mm), standard length(mm) and mass (g) of common carp collected between PNM Weir and Hogback Diversion on ten separate sampling trips during 2001.

Trip	Number of Fish	Flow (ft³/s)	Tot. Effort (hours)	Mean TL (mm)	Mean SL (mm)	Mean Mass (g)	CPUE (fish/hour)
20-22 Feb 2001	1096*	870	29.24	490.74	394.81	1598.39	37.48
13-15 Mar 2001	401*	1,050	25.08	482.33	385.34	1588.03	16.00
26-28 Mar 2001	103	1,800	16.46	474.99	380.85	1567.19	6.26
10-12 Apr 2001	79	1,250	18.17	482.06	381.25	1557.49	4.35
24-26 Apr 2001	68	1,700	15.80	475.12	375.18	1570.69	4.30
8-10 May 2001	107	2,500	14.00	472.64	374.16	1452.87	7.64
10-12 July 2001	297*	1,000	18.47	475.53	376.48	1596.76	16.08
14-15 Aug 2001	164	2,650	10.54	460.41	365.86	1382.29	15.56
11-13 Sept 2001	402*	690	18.20	466.26	374.25	1326.03	22.09
6-7 Nov 2001	357*	550	12.11	454.01	358.91	1391.22	29.48
Totals	**3,074**	**n/a**	**178.05**	**475.35**	**378.72**	**1522.34**	**17.26**

* - length/weight data recorded from a sub sample (401, 257, 228, 101 and 153 respectively).
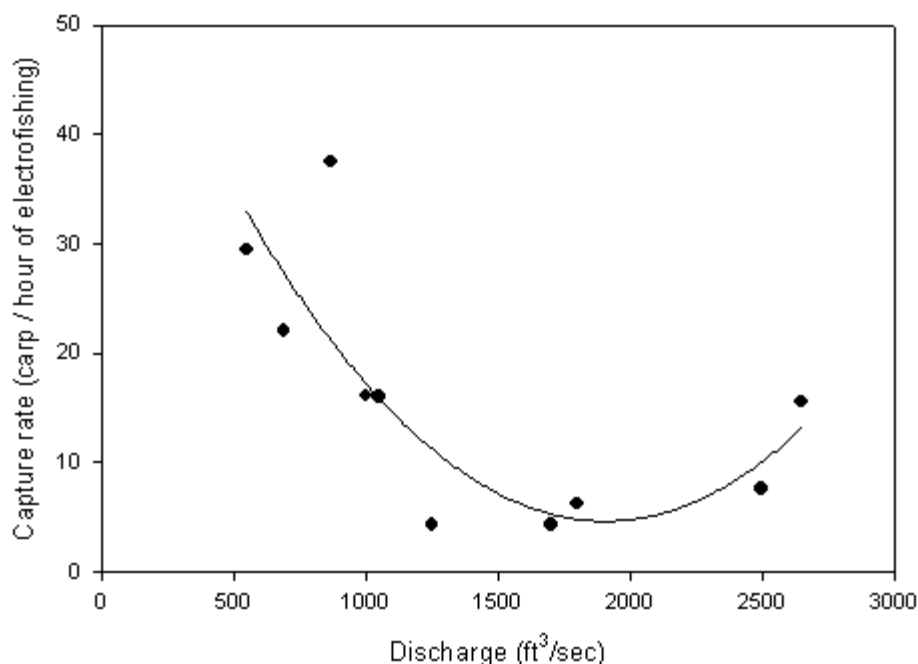
Figure 16. Significant negative correlation observed (r = -0.733; p = 0.016) between discharge and capture rates of common carp collected in the San Juan River from PNM Weir to Hogback Diversion, 2001.

Striped Bass Collections in 2000

A total of 397 striped bass were collected during 2000 adult and razorback monitoring trips. An additional 35 were collected on mechanical removal trips from PNM Weir to Hogback Diversion. These collections represent the largest concentration of striped bass ever to be collected in the San Juan River (Ryden 2001). Of these fish, all but one were of adult size ranging between 457-600 mm total length and 750-2100 g. The majority of striped bass collected were female.

Out of 38 stomachs analyzed, 29 contained whole or partially digested fish and/or arthropods (Table 6). Non-native cyprinids and native catostomids occurred most frequently in stomachs analyzed (44.8% and 41.4%, respectively). Of fish that could be positively identified to species, red shiner (*Cyprinella lutrensis*), flannelmouth sucker (*Catostomus latipinnis*) and speckled dace (*Rhinichthys osculus*) were the most abundant (Table 7).

Table 6. Frequency of occurrence of families of fishes found in striped bass (*Morone saxatilis*) stomachs collected from the San Juan River (collected 19 September to 22 September 2000 and 2 October to 10 October 2000). Cyprinidae is separated into three categories: non native Cyprinidae (*Cyprinella lutrensis*, *Pimephales promelas* and *Cyprinus carpio*); native Cyprinidae (*Gila robusta*, *Ptychocheilus lucius*, *Rhinichthys osculus*) and Cyprinidae (fish that could only be identifiedtofamily).

	Morone saxatilis stomachs n= 29[a]	
	% Occurrence (n)	Number consumed (n)
Catostomidae	41.4 (12)	16
Native Cyprinidae	20.7 (6)	7
Non native Cyprinidae	44.8 (13)	25
Unidentified Cyprinidae	27.6 (8)	26
Ictaluridae	6.9 (2)	3
Centrarchidae	6.9 (2)	2
Unidentifiable fishes	40.0 (11)	17
Arthropoda (crayfish)	13.8 (4)	4
Totals		100

Table 7. Frequency of occurrence of species of fishes found in striped bass stomachs collected on the San Juan River (collected 19 September 2000 to 22 September 2000 and 2 October 2000 to 10 October 2000). Only fish that could be positively identified to species are included.

	Morone saxatilis stomachs n = 29	
Species	% Occurrence (n)	Number consumed (n)
Cyprinus carpio	13.8 (4)	7
Cyprinella lutrensis	31.0 (9)	17
Rhinichthys osculus	20.7 (6)	7
Catostomus discobolus	6.9 (2)	3
Catostomus latipinnis	24.1 (7)	7
Ictalurus punctatus	6.9 (2)	3
Micropterus dolomieui	3.4 (1)	1
Micropterus salmoides	3.4 (1)	1
Totals		46

a - 38 total stomachs were taken. Of the 38, nine stomachs were empty and were therefore excluded from the calculation for frequency of occurrence.

DISCUSSION

Channel Catfish

As seen from continuous years of sampling, total catch rates for channel catfish vary greatly from year to year and reach to reach without significant long term trends. Total channel catfish catch rates increased overall from 1999 to 2000 but not significantly. A contributing factor to elevated channel catfish catch rates was the significant increase of juvenile (60-300mm) fish collected in Reaches 5 and 4. This could have been a direct response to increased removal efforts (Pitlo, 1997). The increase in catch rates of smaller sized fish is similar to observations of over exploited stocks of channel catfish in the Mississippi River (Pitlo, 1997) and angler exploitation in the Powder River, Wyoming (Gerhardt and Hubert, 1991). For example, overharvest in the Mississippi River resulted in (1) declines in yield, (2) increases in the proportion of smaller fish, (3) a narrow range of age groups, (4) high dependance on single year-classes and (5) high mortality rates (Pitlo, 1997). These declines were observed during a relatively long time period, 1955 to 1984 and focused on the over exploitation of larger sized channel catfish. In the San Juan River, removal efforts are concentrated on all size classes. Sexually mature channel catfish as well as sexually immature individuals that would contribute to the breeding population in subsequent years were removed. Theoretically, this type of non-size selective removal would impact the population more rapidly than size selective removal (Smith, 2000).

Understanding reproductive potential and how it relates to size is an important factor in managing channel catfish for both commercial and recreational fisheries. It will also prove to be important for determining the effects of mechanical removal within the San Juan River. Various studies have shown that channel catfish fecundity increases with TL, particularly at 380mm (Helms, 1975; Jearld and Brown, 1971; Raibley and Jahn, 1991). Helms (1975) found that 1 of 10 channel catfish were sexually mature at 330 mm TL producing about 4,500 eggs compared to 5 of 10 at 380 mm TL producing about 41,500. Pitlo (1997) estimated that an increase in slot limits from 330 mm to 380 mm would increase the reproductive potential 10 fold of exploited stocks of channel catfish in the Mississippi River. Hubert (1999) reported on growth rates that showed

channel catfish reached a length > 380 mm by their fourth year. In Oklahoma, 380 mm individuals were also found to be four years old (Hall and Jenkins, 1952). Preliminary age and growth data for the San Juan river indicated that a 380 mm TL individual may be up to seven years old (n = 73, New Mexico Fishery Resources Office files).

Channel catfish size class trends in 2000 followed size class trends from 1998 to 1999 with a higher percentage of juvenile channel catfish (< 300 mm TL) being collected than adults (4,304 juvenile and 1, 903 adults collected in 2000). Although an increase in juvenile catfish catch rates may be attributable to intensive mechanical removal efforts, other environmental factors that may influence catch rates must be considered including discharge, water temperature and turbidity. Past observations have shown that channel catfish may be more readily captured at lower flows compared to higher spring runoff conditions (Buntjer, 1999).

A shift to smaller individuals may be key to removal efforts. Smaller channel catfish are less likely to be sexually mature and, are less fecund if mature (Hubert, 1999). An initial response to removal of larger more sexually mature channel catfish can be an increase in the numbers of smaller size classes, thereby possibly increasing interactions with native fish. Although interactions may initially be increased, continued removal (exploitation) should reduce the numbers of smaller fish collected as well (Pitlo 1997). Additional information on the age at sexual maturity of San Juan river channel catfish would allow for the development of target capture rates for size classes in sub-reaches for removal efforts. These targets, incorporating data collected up to this point and data collected in 2001, will be used to determine the continuation of intensive removal efforts in a specific reach or initiation of repetitive removal efforts in adjacent downstream reaches.

Sampling during 2001 in the PNM Weir to Hogback Diversion reach marked the third year of a continuing study designed to determine the effects intensive mechanical removal has on distribution and abundance of large bodied non-native fishes with emphasis on channel catfish. Initially, channel catfish catch rates were relatively high indicating well established population. Subsequent trips resulted in lower catch rates and mean TL and weight generally declined

suggesting mechanical removal was working, but when post spring runnoff catch rates increased, this success was questioned. These results indicate either a lack of effective removal or channel catfish immigration. The newly constructed fish ladder at Hogback Diversion could allow channel catfish to invade upstream and occupy vacant territories.

An additional study to tag channel catfish with external dangler tags immediately below Hogback Diversion to assess upstream movement was initiated late 2001. On November 5, 2001; a total of 550 channel catfish were collected within 5.5 RM's downstream of Hogback Diversion and equipped with dangler anchor tags. Preliminary re-capture results in 2002, coupled with capture rate data of channel catfish collected in adjacent Reach 5 indicate that these fish may be "stacking up" below the diversion and re-occupying territories vacated through removal efforts when flow conditions are suitable.

Common Carp

Since the introduction of common carp into North American waters in the 1870's, many studies have been conducted to determine the most efficient methods of controlling carp numbers and preventing their domination of the fish community (Tyus and Saunders, 2000; Cooper, 1987). Experiments by Shields (1957) suggested dewatering of habitats supporting eggs and larvae as the best control method. This method proves to be difficult in accomplishing in lotic environments. Other control methods have included seining, construction of fish barrier dams, introduction of predators and uses of fish toxicants (Cooper, 1987).

In the San Juan River, common carp were the fourth most abundant fish collected and the second most abundant non-native collected, occurring in 75.8% of all main channel electrofishing conducted from 1991-1997 (Ryden, 2000). These surveys showed that common carp are widespread and abundant throughout the San Juan River.

Mechanical removal of common carp in the San Juan River has not resulted in long term trends in a reduction of catch rates or mean TL. Comparisons of common carp catch rates riverwide, from

1998 to 1999 showed an increase in all reaches and an increase in TL. However, comparisons between data collected in 1999 and 2000 showed significant decreases in both catch rates and mean TL. Past collection efforts show a narrow range of size classes found with few juvenile (< 250 mm) or YOY common carp collected (Ryden, 2000). Smith (2000) found that the standard deviations of mean TL were small (3% and 2.2%, respectively) for 1998 and 1999 indicating the occurrence of few individuals at the outer limits of the TL frequency distributions. Thus, the lack of significant decreases in mean TL and capture rates of common carp in the San Juan River suggests rapid growth rates and the presence of large numbers of juvenile carp, which occupy backwaters and small secondary channels, habitat types not usually sampled by mainstream electrofishing (Propst and Hobbes, 2000). In 2000, large collections of common carp < 300 mm TL were relatively high and a bi-modal TL distribution was observed (Figure 5). This boost in juvenile and YOY common carp is not easily explained but could be a result of several years of experimental flows from Navajo Reservoir which may have increased suitable habitat conditions for the common carp (Ryden, 2001).

Although no definite conclusions can be reached concerning the efficacy of mechanical removal as a control measure in the distribution and abundance of common carp in the San Juan River, it is recommended that removal efforts continue and results analyzed to determine any long term trends that may surface over time. Additional data regarding growth rates and age class structure as well as identifying specific times and locations for removal efforts to take place will assist in the future management of this species.

Striped Bass

Striped bass may pose a serious threat to native fish in the San Juan River through predation. Although its abundance throughout the river is highly variable, even a few individuals could potentially be detrimental to native fishes (Ryden, 2001). Electrofishing surveys conducted in 2000 showed widespread distribution and high abundance during post runoff upstream as far as PNM Weir. It has been observed that this species will move upstream out of Lake Powell given proper conditions (i.e. water temperature, turbidity) and will move back downstream when

conditions are no longer favorable (personal observation).

A better understanding of the river conditions for and timing of upstream movements along with knowledge of habitat utilization will assist researchers in planning future removal efforts. Increased distribution and abundance of highly predatory fish like striped bass and walleye is of great concern to recovery efforts of native fishes. Introduction of any new non-native fishes through inadvertent stocking or reservoir escapees must be avoided by all means possible.

Recreational Fisheries

Removal of non-native fishes, especially channel catfish and striped bass, in the San Juan River has met with both controversy and praise from the public. Channel catfish were ranked as medium importance in New Mexico, Arizona and Colorado and as low importance in Utah to anglers (Michaletz and Dillard, 1999). In New Mexico, seven of the designated warm water fisheries have reduced limits on channel catfish with all of them being small impoundments (New Mexico Department of Game and Fish, 1999). Increasing demand for channel catfish in "put and take" fisheries has resulted in lack of supply from hatcheries. It was suggested by Smith (2000) that augmentation of hatchery reared channel catfish stocks with wild stocks could alleviate the limited supply of channel catfish in some waters.

Channel catfish transplantation from the San Juan River to closed impoundments within the drainage began in 1997 and is supported by both the Navajo Nation and the New Mexico Department of Game and Fish. Transplant of wild caught channel catfish (up to 15 times larger than typical hatchery-reared fish) transplanted to the Navajo Nation and State of New Mexico managed waters has been met with positive comments from the community and has helped ease tensions concerning the sacrifice of these species during other sampling efforts (Smith, 2000). Transplanting efforts should be concentrated during optimal collection times (i.e. minimal flows, reduced turbidity, etc.). Catch rates of channel catfish collected from PNM Weir to Hogback Diversion during 2001 showed a negative correlation with increases in stream discharge (unpublished data, New Mexico Fishery Resources Office). If transplanting efforts are conducted

during these optimal periods, cost per kilogram may be greatly reduced

The relative cost of removing and transplanting fish by electrofishing is high ($3.15/kg) compared to hatchery production and stocking ($0.31 - $1.25/kg). However, the mutual benefits of non-native removal, for native fishes, and channel catfish transplants may prove most cost effective overall and lessen the need for culture of endangered fishes at federal and state hatcheries (Brooks et al., 2000).

CONCLUSIONS

- Intensive mechanical removal must move to adjacent downstream reaches in an attempt to suppress movement and subsequent re-occupation into areas where removal efforts are currently being conducted

- Mechanical removal efforts corresponded with an overall reduction in mean total length and mass of channel catfish

- Catch rates of channel catfish in 2001 were significantly higher than those of 1999, which can be attributed to increased catch rates of juvenile channel catfish, possibly a bi-product of mechanical removal

- Mechanical removal of common carp has not resulted in any significant changes in capture rates or reductions in size class distribution but is proposed to continue

- Collection of young of year channel catfish and common carp was uncommon

- Preliminary mark/recapture data indicate that channel catfish readily utilized the non-selective fish ladder at Hogback Diversion to occupy upstream reaches

- Transplantation of channel catfish from the San Juan river to closed impoundments within the Basin is supported and investigation into the expansion of this program is highly recommended.

Questions/Concerns Regarding Data Integration for 2002/2003

● Are there other factors (i.e. discharge, water temperature, conductivity, turbidity, julian date, etc.) that are influencing capture rates on large bodied non-native fishes and are these types of data readily available for multiple years?

● Have changes in habitat through flow manipulation made the PNM Weir to Hogback Diversion reach less hospitable to larger catfish or is the decrease in abundance and size class distribution primarily a result of mechanical removal efforts?

● What factors contributed to elevated capture rates of juvenile channel catfish and common carp in 2000? Are these results of flow conditions in prior years?

● What are the native fishes response to intensive mechanical removal from PNM Weir to Hogback Diversion? Positive responses in increased distribution an abundance or negative responses due to elevated subjection to electrofishing?

● When do the majority of channel catfish utilize the non-selective fish ladder in place at Hogback Diversion?

● Are channel catfish "stacking up" in the first couple of miles below Hogback Diversion?

● Can transplantation of channel catfish be expanded basin wide and will it be supported by U.S. Fish and Wildlife Service, the Navajo Nation and state agencies including Utah and Arizona?

● Has channel catfish, especially within the PNM Weir to Hogback Diversion reach, feeding habits changed as a result of a decrease in mean total length?

● Can sampling strategies be improved to maximize removal efforts? What are concerns to survival (or establishment of hatchery raised rare fishes) to native fishes where intensive mechanical removal takes place?

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APPENDIX A
CHANNEL CATFISH CATCH RATE
STATISTICS

Table A-1. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, including all Geomorphic Reaches (6-1) in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 67.118, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.932	1.00	
2001	0.000*	1.000	0.932	1.000

Table A-2. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 0.317, p = 0.813			
	1998	1999	2000	2001
1998	1.000			
1999	1.000	1.000		
2000	0.782	0.892	1.000	
2001	1.000	1.000	0.877	1.000

Table A-3. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 19.303, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.038*	1.000	
2001	0.150	0.294	0.000*	1.000

Table A-4. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 18.784, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.775	1.000	
2001	0.000*	0.988	0.915	1.000

Table A-5. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 15.312, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.001*	0.858	1.000	
2001	0.000*	0.531	0.075	1.000

Table A-6. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 68.884, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.001*	1.000	
2001	0.000*	0.656	0.034*	1.000

Table A-7. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total (juvenile and adult) channel catfish catch rates, Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 11.797, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.220	1.000		
2000	0.170	1.000	1.000	
2001	0.000*	0.003*	0.001*	1.000

Table A-8. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, including all Geomorphic Reaches (6-1) in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 76.964, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.000*	1.000	
2001	0.000*	0.000*	0.986	1.000

Table A-9. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 0.662, p = 0.576			
	1998	1999	2000	2001
1998	1.000			
1999	0.508	1.000		
2000	0.999	0.734	1.000	
2001	0.984	0.811	0.998	1.000

Table A-10. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 36.007, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.998	1.000		
2000	0.000*	0.000*	1.000	
2001	0.015*	0.026*	0.000*	1.000

Table A-11. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 16.877, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.132	1.000		
2000	0.000*	0.004*	1.000	
2001	0.000*	0.005*	0.995	1.000

Table A-12. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 13.048, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.077	1.000		
2000	0.003*	0.929	1.000	
2001	0.000*	0.021*	0.051*	1.000

Table A-13. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 68.816, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.007*	1.000	
2001	0.000*	0.933	0.035	1.000

Table A-14. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of juvenile channel catfish catch rates, Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 11.234, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.068	1.000		
2000	0.118	0.974	1.000	
2001	0.000*	0.020*	0.003*	1.000

Table A-15. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, including all Geomorphic Reaches (6-1), in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 26.425,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.003*	1.000	
2001	0.000*	0.008*	0.994	1.000

Table A-16. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.029,	p = 0.381		
	1998	1999	2000	2001
1998	1.000			
1999	0.746	1.000		
2000	0.374	0.958	1.000	
2001	0.996	0.907	0.634	1.000

Table A-17. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 6.979,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.011*	0.628	1.000	
2001	0.701	0.028*	0.300	1.000

Table A-18. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 17.925,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.700	1.000	
2001	0.000*	0.230	0.873	1.000

Table A-19. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 19.426, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.039*	1.000	
2001	0.000*	0.075	0.993	1.000

Table A-20. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 7.238, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.040*	0.186	1.000	
2001	0.009*	0.545	0.919	1.000

Table A-21. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of adult channel catfish catch rates, Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.802, p = 0.155			
	1998	1999	2000	2001
1998	1.000			
1999	0.959	1.000		
2000	0.992	0.996	1.000	
2001	0.126	0.410	0.241	1.000

FINAL

APPENDIX B
COMMON CARP CATCH RATE
STATISTICS

Table B-1. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , including all Geomorphic Reaches (6-1), in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 14.173, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.002*	0.106	1.000	
2001	0.000*	0.707	0.604	1.000

Table B-2. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.354, p = 0.258			
	1998	1999	2000	2001
1998	1.000			
1999	0.468	1.000		
2000	0.998	0.552	1.000	
2001	0.448	1.000	0.543	1.000

Table B-3. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 13.373, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	1.000	1.000	
2001	0.017*	0.184	0.174	1.000

Table B-4. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 4.616, p = 0.003			
	1998	1999	2000	2001
1998	1.000			
1999	0.003*	1.000		
2000	0.058	0.849	1.000	
2001	0.149	0.550	0.966	1.000

Table B-5. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 20.443, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.000*	0.031*	1.000	
2001	0.000*	0.271	0.715	1.000

Table B-6. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 8.225, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.493	1.000		
2000	0.998	0.598	1.000	
2001	0.000*	0.033*	0.000*	1.000

Table B-7. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of total catch rates of common carp , Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.488, p = 0.068			
	1998	1999	2000	2001
1998	1.000			
1999	0.706	1.000		
2000	1.000	0.789	1.000	
2001	0.068	0.563	0.107	1.000

Table B-8. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , including all Geomorphic Reaches (6-1), in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 10.427, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.984	1.000		
2000	0.000*	0.000*	1.000	
2001	0.506	0.412	0.006*	1.000

Table B-9. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 12.286, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	1.000	1.000		
2000	0.000*	0.000*	1.000	
2001	0.962	0.981	0.000*	1.000

Table B-10. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.549, p = 0.056			
	1998	1999	2000	2001
1998	1.000			
1999	1.000	1.000		
2000	0.088	0.203	1.000	
2001	0.305	0.468	0.969	1.000

Table B-11. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 6.404, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.492	1.000		
2000	0.009*	0.000*	1.000	
2001	0.651	0.081	0.216	1.000

Table B-12. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 3.953, p = 0.008			
	1998	1999	2000	2001
1998	1.000			
1999	0.664	1.000		
2000	1.000	0.724	1.000	
2001	0.061	0.009*	0.076	1.000

Table B-13. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.833, p = 0.141			
	1998	1999	2000	2001
1998	1.000			
1999	0.896	1.000		
2000	0.346	0.124	1.000	
2001	0.920	0.595	0.789	1.000

Table B-14. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of juvenile common carp , Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.364, p = 0.079			
	1998	1999	2000	2001
1998	1.000			
1999	1.000	1.000		
2000	0.101	0.187	1.000	
2001	1.000	1.000	0.203	1.000

Table B-15. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , including all Geomorphic Reaches (6-1), in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 6.873,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.964	0.002*	1.000	
2001	0.324	0.061	0.663	1.000

Table B-16. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 6, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 3.856,	p = 0.010		
	1998	1999	2000	2001
1998	1.000			
1999	0.514	1.000		
2000	0.013*	0.519	1.000	
2001	0.125	0.924	0.862	1.000

Table B-17. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 9.359,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.001*	0.557	1.000	
2001	0.419	0.015*	0.248	1.000

Table B-18. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 3.070,	p = 0.028		
	1998	1999	2000	2001
1998	1.000			
1999	0.020*	1.000		
2000	0.570	0.483	1.000	
2001	0.191	0.810	0.938	1.000

Table B-19. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 17.442, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.001*	0.032*	1.000	
2001	0.000*	0.682	0.263	1.000

Table B-20. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 7.792, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.052	1.000		
2000	0.992	0.026*	1.000	
2001	0.001*	0.699	0.000*	1.000

Table B-21. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of catch rates of adult common carp , Reach 1, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 3.084, p = 0.033			
	1998	1999	2000	2001
1998	1.000			
1999	0.724	1.000		
2000	0.999	0.821	1.000	
2001	0.031*	0.376	0.057	1.000

FINAL

APPENDIX C
CHANNEL CATFISH AND COMMON CARP
MEAN TOTAL LENGTH
STATISTICS

FINAL

Table C-1. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , including all Geomorphic Reaches (6-1) in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 12.208,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.253	0.000*	1.000	
2001	0.011*	0.018*	0.618	1.000

Table C-2. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 6 , in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 6.023,	p = 0.001		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.815	0.020*	1.000	
2001	0.990	0.002*	0.947	1.000

Table C-3. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 24.522,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.000*	1.000		
2000	0.928	0.000*	1.000	
2001	0.105	0.000*	0.337	1.000

Table C-4. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 15.294,	p = 0.000		
	1998	1999	2000	2001
1998	1.000			
1999	0.079	1.000		
2000	0.000*	0.000*	1.000	
2001	0.000*	0.312	0.013*	1.000

Table C-5. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.606,	p = 0.051		
	1998	1999	2000	2001
1998	1.000			
1999	0.030*	1.000		
2000	0.467	0.634	1.000	
2001	0.696	0.310	0.970	1.000

Table C-6. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.687,	p = 0.045		
	1998	1999	2000	2001
1998	1.000			
1999	0.035*	1.000		
2000	0.037*	1.000	1.000	
2001	0.086	0.945	0.962	1.000

Table C-7. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of channel catfish , Reach 1,   in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 3.208,	p = 0.029		
	1998	1999	2000	2001
1998	1.000			
1999	0.099	1.000		
2000	0.377	0.818	1.000	
2001	0..474	0.101	0.949	1.000

Table C-8. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , including all Geomorphic Reaches (6-1) in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 14.189, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.347	1.000		
2000	0.000*	0.000*	1.000	
2001	0.255	0.998	0.000*	1.000

Table C-9. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 6 , in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 40.662, p = 0.000			
	1998	1999	2000	2001
1998	1.000			
1999	0.343	1.000		
2000	0.000*	0.000*	1.000	
2001	0.137	0.999	0.000*	1.000

Table C-10 Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 5, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.988, p = 0.116			
	1998	1999	2000	2001
1998	1.000			
1999	0.109	1.000		
2000	0.471	0.838	1.000	
2001	0.621	0.708	0.995	1.000

Table C-11. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 4, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 0.373, p = 0.773			
	1998	1999	2000	2001
1998	1.000			
1999	0.957	1.000		
2000	0.839	0.993	1.000	
2001	0..997	0.927	0.814	1.000

Table C-12. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 3, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 2.336,	p = 0.0747		
	1998	1999	2000	2001
1998	1.000			
1999	0.054	1.000		
2000	0.519	0.623	1.000	
2001	0.193	0.958	0.911	1.000

Table C-13 Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 2, in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 0.508,	p = 0.678		
	1998	1999	2000	2001
1998	1.000			
1999	0.999	1.000		
2000	0.992	0.999	1.000	
2001	0.870	0.782	0.741	1.000

Table C-14. Kruskal-Wallis non-parametric rank statistics and matrix of Tukey HSD multiple pairwise comparisons of mean total lengths (millimeters) of common carp , Reach 1,   in the San Juan River, 1998-2001 (p < 0.05 = statistically significant)

Kruskal-Wallis:	H-statistic = 1.793,	p = 0.155		
	1998	1999	2000	2001
1998	1.000			
1999	0.193	1.000		
2000	0.996	0.231	1.000	
2001	0.987	0.350	0.999	1.000